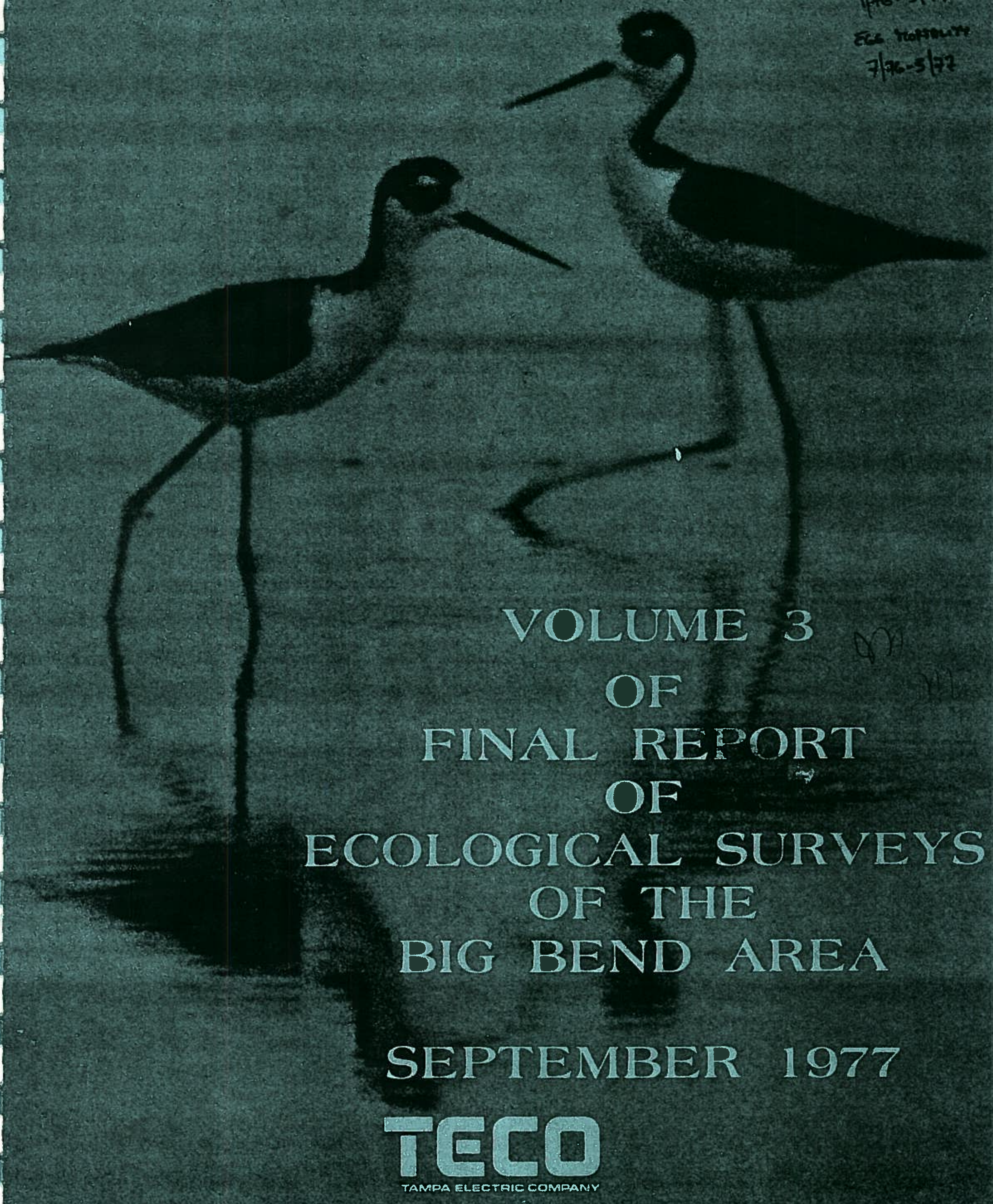
APPENDIX TO
316 DEMONSTRATION VOLUME III

Case Studies - Tampa 5

Entrainment / Impingement / Meroplankton / Ichthyoplankton
1/76-3/77

Egg Mortality
7/76-5/77



VOLUME 3 OF FINAL REPORT OF ECOLOGICAL SURVEYS OF THE BIG BEND AREA

SEPTEMBER 1977

TECO
TAMPA ELECTRIC COMPANY

ECOLOGICAL STUDIES AT BIG BEND STEAM ELECTRIC STATION (TAMPA ELECTRIC COMPANY)

AN ANALYSIS AND SUMMARY OF STUDIES ON THE EFFECTS OF THE COOLING WATER SYSTEM ON AQUATIC FAUNA

A 316 DEMONSTRATION
BIOLOGICAL STUDY

Edited By

Richard D. Garrity
William J. Tiffany III
Selvakumaran Mahadevan

CONSERVATION CONSULTANTS, INC.
P.O. BOX 35
Palmetto, Florida 33561

August, 1977

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CHAPTER FIVE

Part I

A STUDY OF ICHTHYOPLANKTON SEASONALITY AND ENTRAINMENT BY THE BIG BEND POWER PLANT, TAMPA BAY, FLORIDA

BY

T. DUANE PHILLIPS
J. MICHAEL LYONS
JOHN M. DAILY
MELANIE SIGURDSON

AUGUST, 1977

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Dr. Edward D. Houde	University of Miami, RSMAS (sciaenids)
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Dr. Thomas Potthoff	Southeast Fisheries Center, NMFS, Miami (sparids)
Dr. William J. Richards	Southeast Fisheries Center, NMFS, Miami (carangids and triglids)
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LIST OF PARTICIPANTS

Principal Investigator:	T. Duane Phillips B.A. Staff Biologist
Research Assistants:	John M. Daily B.A. Staff Biologist
	J. Michael Lyons B.A. Staff Biologist
	Melanie J. Sigurdson Marine Science Technician
	Kimberly A. Mason Marine Science Technician
	Anne M. Schroedl Marine Science Technician

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INTRODUCTION

A large number of fish species, many of commercial importance, are planktonic during their egg and larval stages. Their relative immobility and small size make them susceptible to entrainment through power plants which use seawater for once-through condenser cooling. Entrained organisms are subjected to many stresses during plant passage including thermal shock, rapid pressure changes, mechanical damage, and exposure to chemicals used to control the growth of fouling organisms (Clark and Brownell, 1973; Coutant, 1974; Marcy, 1974). These eggs and larvae are also exposed to elevated temperatures during passage through plant discharge canals. The importance of power plant mortality is unknown, but is related to the quantity of organisms withdrawn at plant intakes and the species affected (Marcy, 1974).

Estuarine areas, such as those near the Big Bend plant, are known to be important nursery areas for many species of sport and commercial fishes (Pearse and Gunter, 1957; Skud and Wilson, 1960; Sykes and Finucane, 1966; Gallaway and Strawn, 1974; Carr and Giesel, 1975). Young fishes which live in these environments are sensitive to a variety of fluctuations in the environment, including temperature (deSylva, 1969; Austin, 1973). Fishes living in water in the 25-30°C temperature range, the range normally experienced in the source water of the Big Bend plant during summertime (TECO, 1975a), are already living at temperatures close to their thermal death point (Mayer, 1914; Voss et al, 1969). Rapid increase in water temperature above this level may have detrimental effects upon individual organisms. Losses of ichthyoplankton caused by plant entrainment and temperature increase represent a larger impact on the ultimate adult populations over a larger geographical area than do similar losses of phytoplankton or zooplankton because of the longer regeneration time and life cycle of fishes (Morgan and Stross, 1969; Mihursky, 1969; Marcy, 1974).

Power plant induced mortality is not restricted to rapid temperature increases. Marcy (1973) reported 100% mortality of larval fish passing through the Connecticut Yankee Plant, but he attributed only 20% to thermal effects. He ascribed the remainder of the mortality to mechanical abrasion caused by passage through the condenser tubes.

Studies at other power plants (Marcy, 1971; Edsall and Yocum, 1972; Atomic Energy Commission, 1973; Florida Power Corporation, 1975) have estimated entrainment mortalities ranging from 100 million individuals per year to as high as 164.5 million individuals per day. It is difficult to determine the significance of these numbers without knowledge of the abundance, rate of production, and natural mortality rates of the populations from which these individuals came.

Literature Review

There has been little work done concerning the abundance and distribution of fishes of the Tampa Bay area. The most comprehensive work to date is Springer and Woodburn's (1960) study of the adult fishes in the vicinity of St. Petersburg. Their study dealt almost entirely with juveniles and adults of the area, although some information concerning spawning seasons, based on the collection of ripe or nearly-ripe adults, was given. Some information concerning food habits of various species was also provided. They did provide a systematic listing of the fish species found in the area. Additions to the list have been reported by Springer (1961) and Moe and Martin (1965).

Kelly and Dragovich (1967) studied the zooplankton of the Bay system, but they provided little information on the ichthyoplankton. Fish eggs were not identified and larvae were identified only to family. Sykes and Finucane (1966) outlined the distribution of immature forms of commercially important fish species in the Bay area. They did not, however, provide information dealing with the distribution of either eggs or smaller larvae.

Some of the most useful information elucidating the seasonal distribution and relative abundance of juvenile and adult fishes in the vicinity of the Big Bend plant was gained from compiling five and one half years worth of data gathered during the continuing studies at Big Bend. This information has been summarized in the ichthyoplankton section of a previous report (Phillips, 1976b).

Study Objectives

Ichthyoplankton sampling in the vicinity of the Big Bend plant began in August, 1975. The specific objectives of the program as outlined in the Prospectus for Studies (Conservation Consultants, Inc., 1975) were to "determine the number and kinds of fish eggs and larvae entrained by the plant and their viability after plant passage." This portion of the report will deal primarily with the first part of the objectives (i.e. numbers and kinds of eggs and larvae entrained). Comparisons between estimated numbers of eggs entrained and the number of eggs present within the study area will be attempted for selected species. Viability of entrained eggs and larvae will be discussed in Ichthyoplankton Studies, Part II, Rearing Studies.

Although not specifically requested by the regulatory agencies, much information concerning species composition, seasonal distribution, and abundance of fish eggs and larvae within the study area has been obtained as part of this program. Some of this information has been presented in previous reports (Phillips, 1976a; 1976b; 1976c; 1977a; 1977b). Additional discussion of these factors will be presented in this report.

Study Limitations

Sampling Efficiency

In any biological sampling program, quantitative estimates of species abundance are biased by the efficiency of the collecting gear. The efficiency of plankton nets used for ichthyoplankton sampling depends on several factors, including initial filtering rate of the net, clogging of the mesh, extrusion of eggs and larvae through the mesh, and avoidance of the net by larger individuals. A discussion of these factors can be found in Tranter and Heron (1967), Mahnken and Jossi (1967), Tranter and Smith (1968), Vannucci (1968), Clutter and Auraka (1968) and Barkley (1972). A brief discussion of sampling inefficiency during the study, due to clogging, extrusion and avoidance, is presented in the following paragraphs.

During the course of sampling at Big Bend, the problem of net clogging was probably one of the most important factors affecting the efficiency of the gear used. During winter sampling periods, large numbers of ctenophores were encountered at sampling stations. They rapidly filled the cod-end container and clogged the net mesh, preventing long tows. Spring and summer sampling periods were plagued by net clogging caused by the presence of large numbers of chain diatoms. No attempts have been made to quantify the reduced efficiency of the sampling gear, but it is assumed that ichthyoplankton abundance estimates are biased on the low side.

Extrusion of eggs and larvae through the net mesh was probably not a significant problem, since a 363 μm mesh net was used rather than a 505 μm mesh net, as recommended for ichthyoplankton sampling by UNESCO (1975). The eggs and larvae of most species common in the Big Bend area range upward in size from 0.5 mm. Many samples contained larvae that were smaller than previously reported hatching lengths.

Avoidance of plankton nets by fish larvae is another problem encountered in ichthyoplankton surveys. Several explanations for net avoidance have been suggested. These include vertical migration by the larvae, patchiness, detection of pressure waves in front of the net by the larvae and visual observation of the net by the larvae (Scotten et al., 1973). Additional factors affecting catch size, and possibly related to net avoidance, include differences observed when sampling occurs during different moon phases, during different tidal phases and between daytime and nighttime collections (Bridger, 1956; deSylva, 1970; Fore and Baxter, 1972). In an attempt to minimize some of these avoidance factors, sampling at Big Bend was designed to occur during both day and night, always within the same 24-hour period, and on the same tide phase within that period whenever possible. Again, no attempt was made to quantify net avoidance, but it is assumed that these factors caused the estimates of the populations to be on the low side.

Plankton Patchiness

A well known phenomenon affecting the accuracy of plankton surveys is that of patchiness. Cushing (1962) suggested that predators aggregate near their prey, thus creating areas of greater abundance, or patches. Patches have been shown to range in size from only a few meters diameter to as large as 60 km in diameter (Cushing, 1962). The size of ichthyoplankton patches in the vicinity of the Big Bend plant is unknown; however, it is probably safe to assume that they are on the order of meters or hundreds of meters in diameter rather than kilometers. This assumption is based upon the known schooling behavior of most of the fishes with pelagic eggs that are common near the plant. Spawning would tend to occur in a relatively small, localized area within and near the school of spawners, and with the poor flushing characteristics of Tampa Bay (Ross, 1973), patches of eggs and larvae would be less likely to be dispersed by currents.

Wiebe and Holland (1968) showed that a net of 100 cm mouth diameter sampled more accurately than one of only 25 cm diameter. In a computer simulation of zooplankton patchiness and its effect on sampling error, Wiebe (1971) demonstrated that precision in sampling small patches (7.5 to 42.5 m/side) was not directly related to increases in the volume of water filtered, but rather to sampling the "right" number of patches. He found that increased accuracy could be gained by making longer tows. Sampling error associated with smaller plankton patches should have been lessened during studies at Big Bend by the combined use of a large net (100 cm diameter) with relatively long tows (up to 100 m^3 filtered).

Sorting Efficiency

Fifty samples were randomly selected to be re-sorted to check the efficiency of initial sorting. Procedures used to re-sort samples followed those outlined by Clark, et al. (1969, 1970). For samples which initially contained large numbers of larvae, or for samples containing large volumes of zooplankton, three 10 ml aliquots were withdrawn at random and sorted for additional larvae. If the number of non-anchovy larvae in the three aliquots exceeded ten percent of the total number originally found in the sample (on an extrapolated volume basis), the entire sample was sorted a second time. In the case of samples which contained only low numbers of larvae initially, the entire sample was resorted. To eliminate bias, no sample was resorted by the same person who sorted it initially. The number of larvae found when samples were resorted was used to calculate a "percentage missed" on initial sorting. Due to the limitations of time and manpower, it was not possible to resort all samples.

Mean sorting efficiency, for non-anchovy larvae as determined from the fifty resorted samples, was 92.9% (i.e. 7.1% missed on initial sorting). Spring and summer samples contained a larger number of 'missed' larvae than samples collected during the fall and winter months.

Lack of a Water Current Study

As previously stated, many species of fish are planktonic during their egg and early larval stages. Due to their small size and relative immobility, they drift more or less passively with the water currents. The present ichthyoplankton survey provides information on the number of eggs and larvae in a given area at the time they are collected. However, a knowledge of circulation patterns in the study area could also provide information on the location of eggs and larvae during the past and at future times, as well as on the length of time that eggs and larvae remain in a given area. This information is useful in determining both population size and the proportion of a population entrained by the power plant.

Only one study of the currents in the vicinity of the plant is extant (Stone and Webster, 1970). This study was conducted during an eight-hour period on October 9, 1969, previous to the start-up of the first unit at Big Bend. Results of this study provide little information concerning the currents near the plant since the study area was small (nine square miles), the duration of the study short, and it was concluded that wind effects during the time of the survey were significant.

A computer simulation of the currents within Tampa Bay was attempted by Ross (1973). Although a counterclockwise gyre was reported offshore from the power plant, this area was not studied in sufficient detail to determine either the source of plant cooling water or the source and fate of water present at open bay ichthyoplankton stations (E-5, B/C-5, A-5, 0-17).

Identifications

Two hundred and eighty-seven species, representing eighty families of fish (excluding sharks, skates and rays), have been reported from the Tampa Bay area (Springer and Woodburn, 1960; Springer, 1961; Moe and Martin, 1965; Powell, Dwinell and Dwinell, 1972). Of these, only 30% (86 species) have been described during their egg and larval stages (many of these descriptions are not of species present at Big Bend, but of closely related species within the same genera). During ichthyoplankton studies at Big Bend, eggs and larvae representing forty one species from twenty-two families have been collected. Many of the identifications made as part of this program are only tentative and have been so noted in previous reports. Specific problems of identification are mentioned in the discussion of seasonality and entrainment.

Attempts were made to identify all eggs and larvae to the species level; however, this was not possible in many cases. Egg identifications are accurate to at least the family level, with some of the more common forms accurate to the genus or species level. Larval identifications are somewhat easier to make, and in most cases, are accurate to at least the genus level. Many of the more common larvae were identified accurately to the species level. Identifications of most species were verified by experts in other parts of the southeast U. S. (see Acknowledgements). Identifications of several species, previously undescribed, were made from size series of larvae assembled from plankton collections. Larvae smaller than 2.5 mm SL presented difficulties and, in many cases, were not identified below genus.

METHODS

Sample Collection and Sorting

Methods utilized during the ichthyoplankton program have been discussed in previous reports (TECO, 1975b; Phillips, 1976b) but will be reviewed herein.

Ten stations in the vicinity of the plant (Figure 5.1) were sampled at two week intervals from January, 1976 through March, 1977. Samples were collected during both the daytime and at night on the same tide phases. Inclement weather and boat breakdown forced the postponement of sampling on several occasions. Plankton samples were collected with a 363 μm mesh, one meter mouth diameter, metered plankton net towed at a speed of approximately 2 knots behind a 24-foot outboard boat. The net was weighted and allowed to sink at the start of each tow. This technique resulted in the net fishing an oblique trajectory, starting near the bottom and ending at the surface. Efforts were made to filter as much water as possible and to try to approach 100 m^3 as recommended by UNESCO (1975). The volume of water filtered was limited on numerous occasions, due to extreme net clogging, caused either by dense phytoplankton and zooplankton blooms or by large numbers of ctenophores.

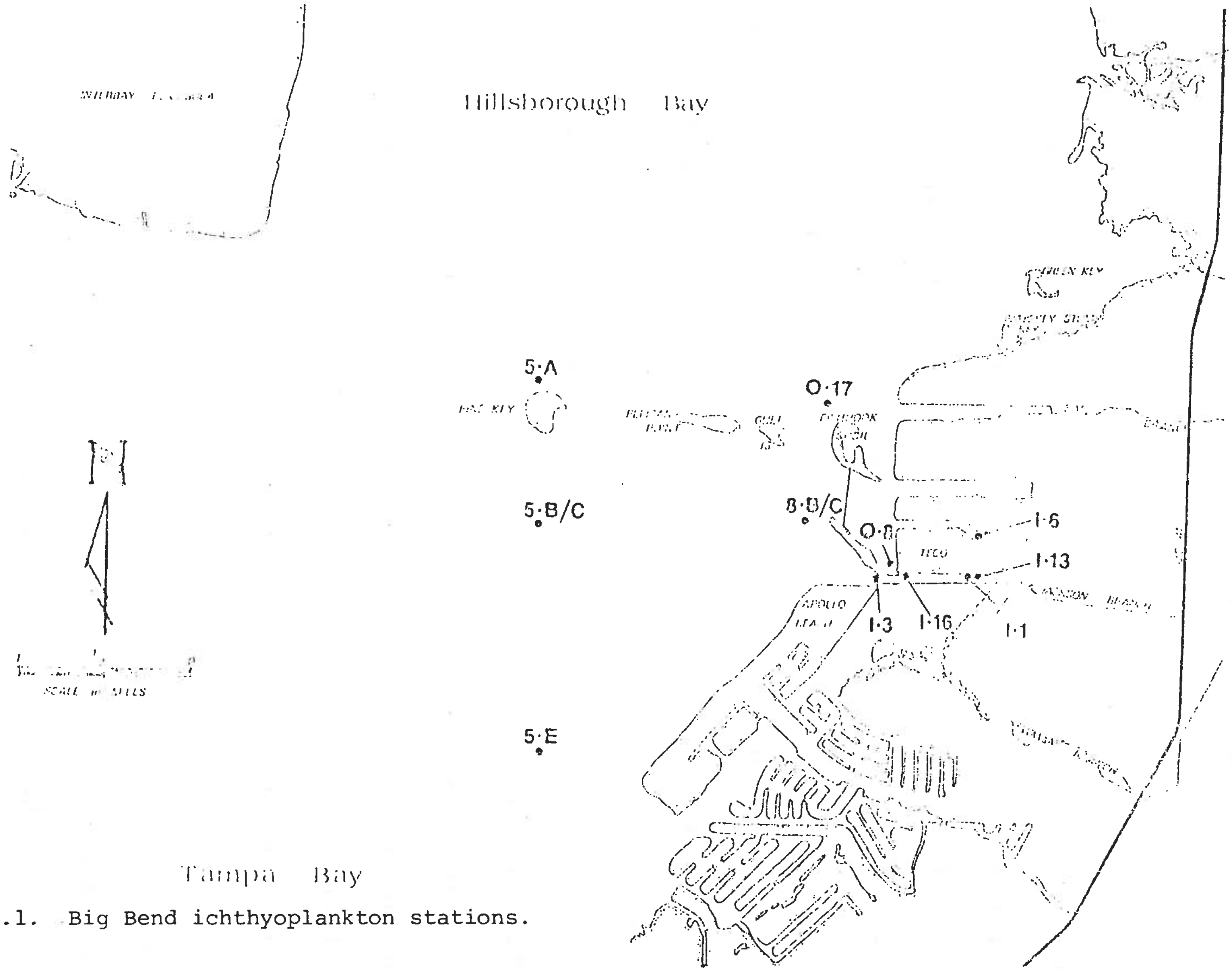


Figure 5.1. Big Bend ichthyoplankton stations.

One liter glass bottles were used as cod end containers for each sample collected. A measured amount of buffered formalin was added to each sample immediately after collection to give a final concentration of 5%. The plankton net was washed immediately after each tow to insure that there would be no cumulative net clogging or contamination.

Physical data, consisting of station depth, air temperature, surface, mid-depth and bottom water temperature, salinity and dissolved oxygen, was taken at each station prior to sample collection. Surface, mid-depth, and bottom water samples were collected with a PVC Van Dorn bottle and returned to the laboratory for analysis of water turbidity. Instruments used to collect physical data have been listed in a previous report (TECO, 1975b).

All samples were sorted with the aid of binocular dissecting microscopes using 10-15X magnification. Each microscope was fitted with an ocular micrometer. The standard length (SL), i.e. the straight-line distance from the most anterior part of the head to the tip of the notochord (Mansueti and Hardy, 1967) measured to the nearest one-tenth millimeter, was recorded for the first fifty individuals of each species. If there were fewer than fifty individuals of a species in a sample, all individuals of that species were measured. All larvae, except those of the bay anchovy, Anchoa mitchilli, were removed from each sample and placed in numbered vials. Anchovy larvae were not removed from samples because they were so numerous. They were counted, and the total number of anchovy larvae in each sample was recorded. The contents of each vial were later reexamined under an Olympus dark-field dissecting microscope at 20-25X magnification for verification of the initial identifications.

Three random 10 ml aliquots were withdrawn from each sample and sorted for eggs. If there were 100 or more eggs of a particular species in each aliquot, the number of eggs contained in the aliquots was used to extrapolate the number of eggs in the entire sample on a volume basis. The entire sample was sorted for eggs of any species with fewer than 100 eggs in the first aliquot. Representative numbers of eggs of each species were placed in numbered vials for later verification of identifications.

All eggs and larvae were identified to the lowest taxon possible, based upon descriptions given in current literature. In addition, confirmation of our identifications were obtained from scientists at the Florida Department of Natural Resources; the University of Miami, Rosenstiel School of Marine and Atmospheric Science; the Southeast Fisheries Center, National Marine Fisheries Service, Miami; and the University of Southwestern Louisiana. In most cases, larval identifications are accurate to the genus level. Egg identifications are accurate at least to the family level. A complete listing of literature used to aid in egg and larval identifications is given in Appendix 5.A.

Replicate Samples

In order to estimate the possible variability that might be expected for ichthyoplankton samples in the Big Bend area, a series of replicate tows were collected on one date (April 14, 1977). Six consecutive plankton tows were made at each of two stations (A-5, an open bay station; I-1, the plant discharge). Replicate samples were collected and sorted as described for routine ichthyoplankton samples.

RESULTS AND DISCUSSION

Replicate Samples

The results of the six consecutive tows taken at station I-1 and A-5 on April 14, 1977 are presented in Tables 5.1-5.4. For each species, the number of individuals per $100m^3$ reported represents the mean value of all six tows at one station. Coefficients of variation were calculated with the following equation from Eberhardt and Gilbert (1975):

$$C.V. = \frac{\text{standard deviation}}{\text{mean}} = \frac{s}{\bar{x}}$$

The coefficients of variation for individual larval species range from 0.21 - 2.46 at I-1 and from 0.70 - 2.86 at A-5. The lowest coefficient of variation at station I-1, and second lowest at station A-5 was obtained for *Anchoa mitchilli*. This is not surprising since this species is by far the most abundant species collected, representing 82.4% of the larvae collected at

Table 5.1. Mean number per $100m^3$ and calculated coefficients of variation for fish eggs collected in six consecutive tows at station I-1 (plant discharge).

Species	Mean Number Per $100m^3$ Filtered	Coefficient of Variation
Anchoa mitchilli (bay anchovy)	83.33	0.22
?Sciaenidae	6.33	1.11
TOTAL	89.67	0.17

Table 5.2. Mean number per $100m^3$ and calculated coefficients of variation for fish eggs collected in six consecutive tows at station A-5 (open bay).

Species	Mean Number Per $100m^3$ Filtered	Coefficient of Variation
?Engraulidae	55.67	0.35
Anchoa hepsetus (striped anchovy)	3.67	1.39
Anchoa mitchilli (bay anchovy)	2915.67	0.13
?Sciaenidae	226.00	0.32
?Prionotus	0.67	2.45
Achirus lineatus (lined sole)	1.33	1.62
TOTAL	3203.00	0.14

Table 5.3. Mean number per $100m^3$ and calculated coefficients of variation for fish larvae collected in six consecutive tows at station I-1 (plant discharge).

Species	Mean Number Per $100m^3$ Filtered	Coefficient of Variation
Anchoa mitchilli (bay anchovy)	376.50	0.21
Syngnathus sp. (pipefish)	0.83	2.46
Cynoscion (?*arenarius*) (sand seatrout)	1.00	2.45
Menticirrhus saxatilis (Northern kingfish)	1.67	1.54
Sciaenidae?	3.17	2.45
Hypsoblennius hentzi (feather blenny)	1.83	2.45
Gobiosoma robustum (code goby)	21.67	0.64
?*Microgobius*	2.67	1.10
Microgobius gulosus (clown goby)	43.50	0.58
Unidentified goby	0.67	2.43
Achirus lineatus (lined sole)	2.50	1.12
Too Damaged to ID	0.83	2.46
TOTAL	456.83	0.22

Table 5.4. Mean number per $100m^3$ and calculated coefficients of variation for fish larvae collected in six consecutive tows at station A-5 (open bay).

Species	Mean Number Per $100m^3$ Filtered	Coefficient of Variation
Brevoortia sp.	1.17	2.86
Anchoa mitchilli (bay anchovy)	7053.50	0.73
Strongylura timucu (timucu)	0.50	2.44
Membras martinica (rough silverside)	11.33	0.70
Orthopristis chrysoptera (pigfish)	0.67	2.43
Cynoscion arenarius (sand seatrout)	65.33	1.49
Cynoscion (?arenarius)	61.67	1.56
Menticirrhus saxatilis (Northern kingfish)	51.00	0.95
Pogonias cromis (black drum)	0.83	2.46
?Sciaenidae	5.17	1.56
Hypsoblennius hentzi (feather blenny)	4.17	1.68
Microgobius gulosus (clown goby)	2.17	1.11
Achirus lineatus (lined sole)	1.33	1.56
Unidentified	2.83	1.85
Too damaged to ID	0.67	2.43
TOTAL	7262.33	0.73

station I-1 and 97.1% of the larvae collected at station A-5. This dominance by anchovy larvae is reflected in the total coefficient of variation, which is equal (station A-5) or virtually equal (station I-1) to the _A. mitchilli_ coefficient of variation. Much higher coefficients of variation were found for almost all of the other, less numerous, larval species collected.

The coefficients of variation for the egg taxa also show much variation. Again, the lowest values at each station were found for _Anchoa mitchilli_.

Species Composition & Seasonal Patterns

The results of the ichthyoplankton sampling between January, 1976 to March, 1977 have been presented in past quarterly reports (Phillips, 1976b; 1976c; 1977a; 1977b; 1977c).

Larvae from twenty-two families of fish were collected during the fifteen months of ichthyoplankton sampling (January, 1976 to March, 1977). Forty one species were represented by these larvae, although this number could be slightly higher or lower because of some uncertain identifications at the species level. Engraulid (anchovy) larvae were the dominant type, constituting 87.4% of all larvae collected. Two, or possibly three species of engraulids were represented in the collections, although _Anchoa mitchilli_ (bay anchovy) larvae were by far the most numerous. Larval sciaenids (drums) were second in abundance, accounting for 3.9% of all larvae taken. The family with the most species was the Sciaenidae, with seven species from five genera. Larvae of six of the twenty-two families recorded constituted 98.3% of all larvae collected. This information is summarized in Table 5.5.

Eggs from twelve families were collected. Of these, engraulid and sciaenid eggs accounted for 73.1% and 26.2% respectively of all eggs collected, and together these two families represented 99.3% of the eggs taken during the fifteen months. This information is also summarized in Table 5.5.

Seasonality of the Big Bend ichthyoplankton was discussed in a previous report (Phillips, 1977b), but will be briefly reviewed here. Although some spawning occurred during each month of 1976, peak densities of both eggs and larvae were noted between the months of March and October. The total number of eggs and larvae collected each month is presented in Figure 5.2. *A. mitchilli* eggs and larvae dominated on most sampling dates during this period. Other species which reached their greatest abundance during spring and summer include several species of sciaenids, (drums), a clupeid, *Harengula jaguana* (scaled sardine), two species of carangids (jacks), a sparid, *Archosargus probatocephalus* (sheepshead), and the lined sole, *Achirus lineatus*.

Table 5.5. Percent of total eggs and larvae taken during ichthyoplankton sampling at Big Bend, by family.

LARVAE		EGGS	
Family	% of Total	Family	% of Total
Engraulidae	87.4	Engraulidae	73.1
Sciaenidae	3.9	Sciaenidae	26.2
Gobiidae	2.7	Carangidae	0.4
Pomadasyidae	2.1	Clupeidae	0.2
Carangidae	1.1	Soleidae	
Sparidae	1.1	Triglidae	
Clupeidae	0.5	Pomadasyidae	
Blenniidae	0.4	Cyprinodontidae	
Soleidae	0.2	Ephippidae	
Triglidae	0.2	Belonidae	
Atherinidae	0.1	Atherinidae	
Gobiesocidae		Gobiidae	
Syngnathidae			
Cynoglossidae			
Ephippidae			
Ophichthidae			
Tetraodontidae			
Mugilidae			
Belonidae			
Bothidae			
Cyprinodontidae			
Gerreidae			

Larvae: Engraulidae through Sparidae together 98.3%; Gobiesocidae through Gerreidae 0.3% (total).

Eggs: Engraulidae and Sciaenidae together 99.3%; Soleidae through Gobiidae 0.1% (total).

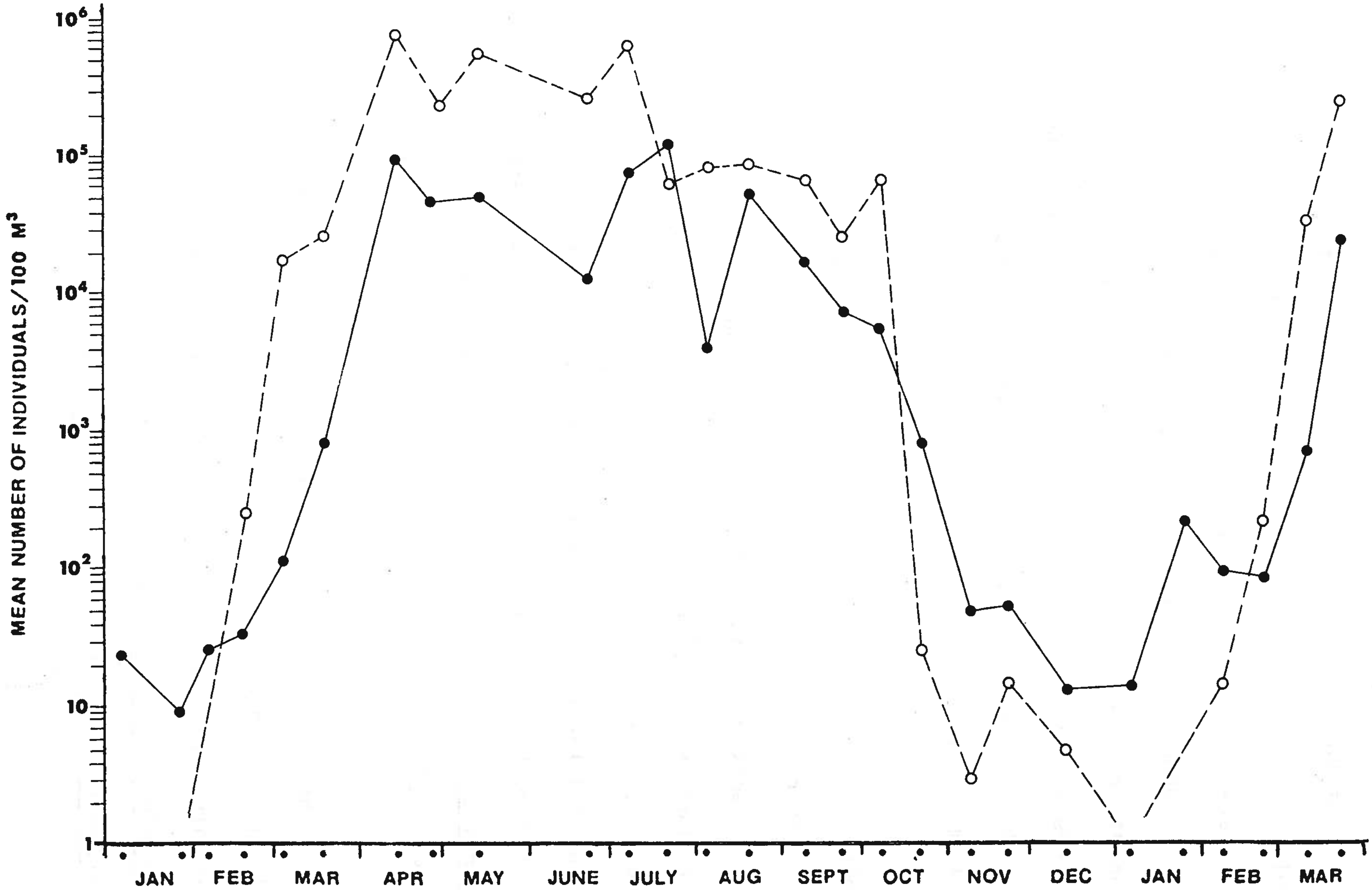


Figure 5.2. Seasonal abundance of total eggs (o---o) and total larvae (●——●), January, 1976 - March, 1977.

The initiation of spawning in the spring by most species can probably be attributed to a variety of factors, including seasonal increases in water temperatures caused by solar heating, the abundance of planktonic food organisms, and favorable day lengths at this time of year. Gunter (1945) found that spawning along the Texas coast was related to water temperatures, and he provided a list of species which begin breeding when specified temperatures are reached.

Spawning at Big Bend continued throughout the summer months when water temperatures were as high as 32° to $35^{\circ}C$.

Fall represented the time of year when spawning tapered off and, for many species, ceased altogether. This decline was most noticeable because of the absence of both anchovy and drum eggs and larvae after about mid-October. Several species including two atherinids (silversides), the skilletfish, Gobiesox strumosus and the gobies and blennys continued to spawn at low levels throughout the fall and even into the winter months.

Little spawning occurred during winter months (December through February, 1976 and 1977) and most collections contained no eggs and only a few larvae. Recently hatched feather blenny larvae (Hypsoblennius hentzi) were taken on all sampling dates. Menhaden (Brevoortia spp.), pinfish (Lagodon rhomboides), and spot (Leiostomus xanthurus) larvae and juveniles were taken in January and February of both 1976 and 1977. These three species spawn somewhere south of the study area (possibly in the Gulf) and migrate into the area at a size usually exceeding 12mm SL. Leptocephalus larvae of the speckled worm eel, Myrophis punctatus, absent in samples from 1976, were taken in January and February, 1977.

A graph summarizing the months of occurrence of all species collected during the ichthyoplankton program is presented in Appendix 7.B.

Seasonal Distribution of Selected Species

CLUPEIDAE - herrings

At least two species of clupeids have been collected during routine ichthyoplankton sampling at Big Bend. These include menhaden eggs and larvae identified only as Brevoortia sp. (because of the confusion generated by the presence in the area of three members of this genus, B. patronus, B. smithi and their hybrid B. patronus x smithi [Dahlberg, 1970]) and eggs and larvae of the scaled sardine, Harengula jaguana Poey.

Brevoortia larvae are apparently spawned in the Gulf of Mexico and migrate into the Big Bend area during January and February after having reached a size of 10-15mm SL. Larval menhadens were usually taken in greater numbers at open bay stations rather than near plant intakes and discharges. Although larvae were collected in January and February of both 1976 and 1977, numbers were usually low. Adults have rarely been taken in the vicinity of the plant (see Chapter 8). It is probable that plant impact on this species is relatively insignificant.

Eggs and larvae of the scaled sardine, H. jaguana, were present within the study area from late April through August, 1976. This species has a slight commercial value as a baitfish, but stocks in the Big Bend area are not fully exploited for this purpose. Mean numbers per $100m^3$ for both eggs and larvae are presented graphically in Figure 5.3. Eggs were always more numerous than larvae except on July 20, 1976, but densities of both were always low, indicating that the waters in the vicinity of the plant may not be a major spawning area for the species. H. jaguana eggs were most numerous on May 13, 1976 and declined in number through August. The late spring and summer spawning season observed in Tampa Bay coincides with the spawning season for the species in other parts of its range (Gunter, 1945; Martinez and Houde, 1975).

ENGRAULIDAE - anchovies

Engraulid eggs and larvae were more abundant in Big Bend ichthyoplankton samples than those of any other family, accounting for 87.4% of all larvae and 73.1% of all eggs taken during the

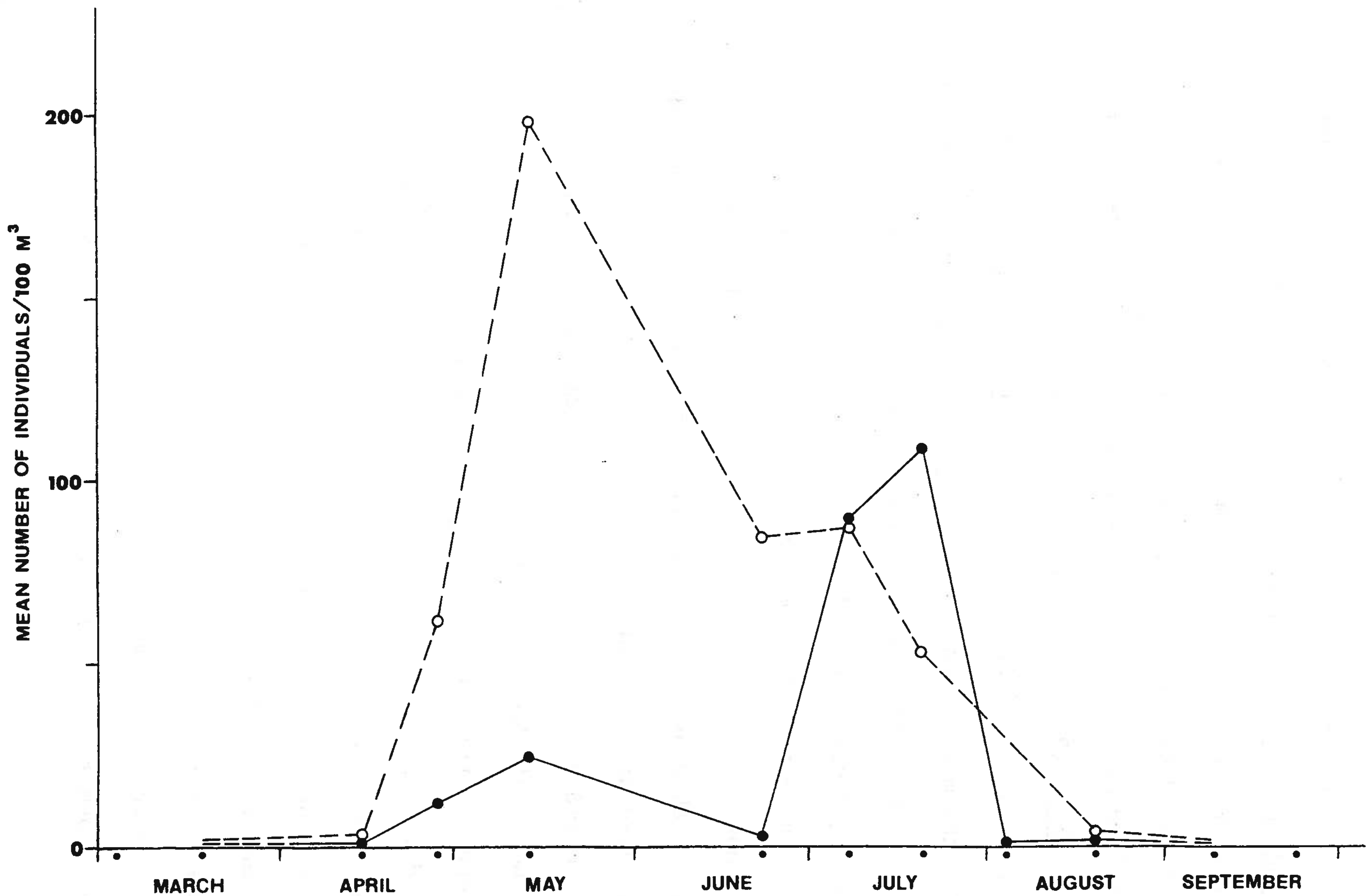


Figure 5.3. Seasonal abundance of _Harengula jaguana_ (scaled sardine) eggs (o---o) and larvae (●——●) during, 1976.

fifteen months of sampling. Eggs and larvae of both the striped anchovy, Anchoa hepsetus (Linnaeus) and the bay anchovy, A. mitchilli (Valenciennes) were common in spring and summer samples. A third type of anchovy egg, tentatively considered as unidentified engraulid? and, possibly belonging to the Cuban anchovy, A. cubana (Poey), was present in samples collected between March and early October, 1976. A. mitchilli eggs and larvae were the most commonly collected engraulid, and frequently, were more numerous than the eggs and larvae of any other species.

A. hepsetus eggs were taken from early March through late June, 1976, but were most numerous in late April and early May. Striped anchovy larvae were collected from April through July and reached peak densities in June and early July. The spawning season observed at Big Bend during 1976 corresponds to the April-July breeding season reported by Hildebrand and Cable (1930) at Beaufort, North Carolina.

Seasonal distribution of A. mitchilli eggs and larvae is illustrated in Figure 5.4. Eggs were first taken in early March, 1976 and were collected regularly through late October, 1976. Peak densities occurred from April through July. The lower numbers taken after July may represent a second spawning by the same individuals or may reflect initial spawning by a smaller number of late maturing females. Lack of detailed fecundity information, particularly data concerning the stages

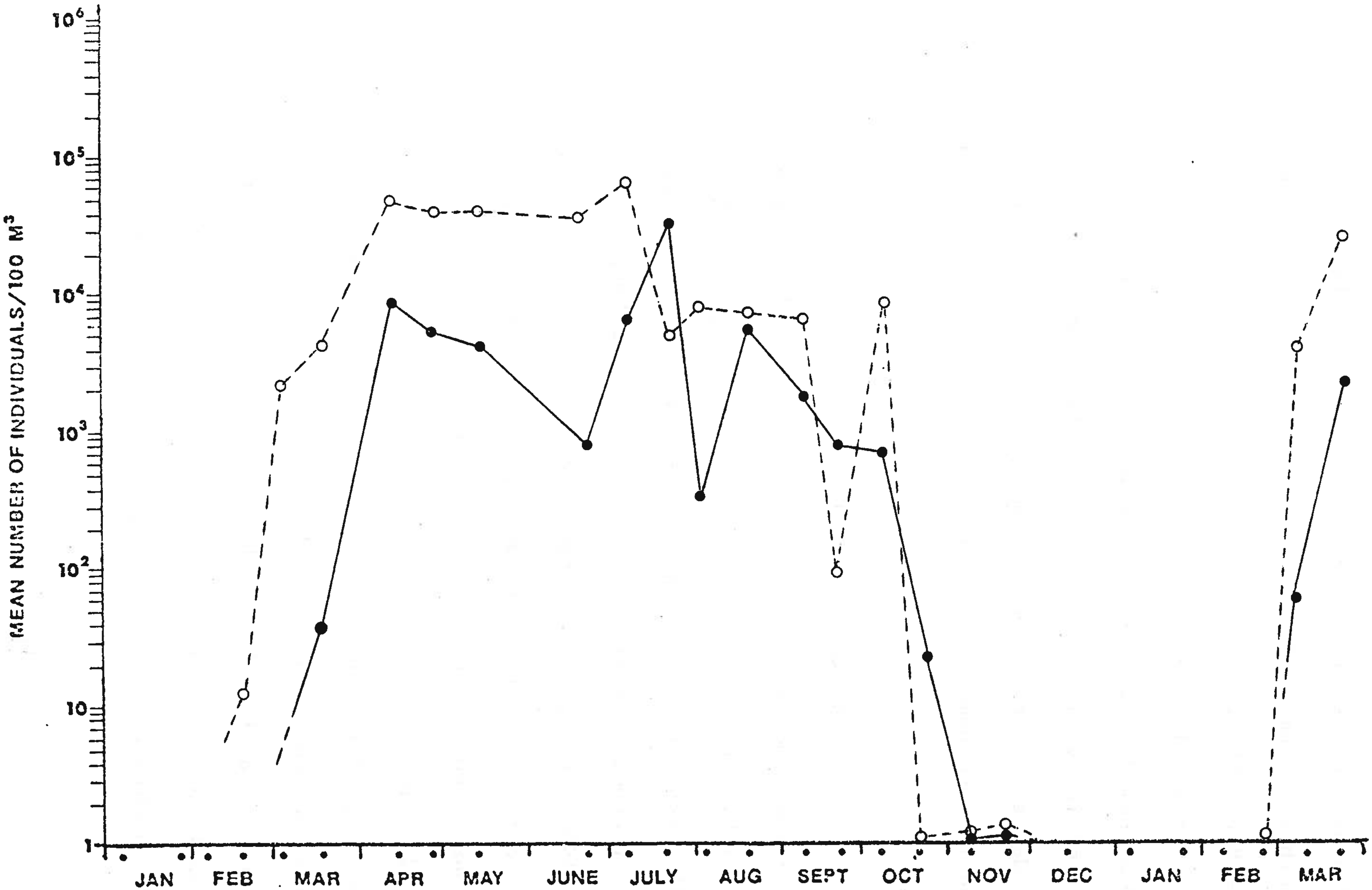


Figure 5.4. Seasonal abundance of <u>Anchoa mitchilli</u> (bay anchovy) eggs (o---o) and larvae (●——●), January, 1976 - March, 1977.

of developing oocytes within the ovaries of maturing females, makes further determination impossible. Larvae were collected from late March through early November. Peak densities occurred from April through October. Low numbers of larvae in samples from June 22, 1976 and August 3, 1976 probably reflect sampling variability since the number of eggs taken on these dates remained high. A. mitchilli eggs and larvae were usually more numerous at open bay stations than near the plant.

GOBIESOCIDAE - clingfishes

The clingfishes were represented in Big Bend ichthyoplankton collections by larvae of one species, Gobiesox strumosus Cope, the skilletfish. Eggs of this species are demersal and are normally attached to shell fragments or other substrate (Runyan, 1961) and were never taken in plankton collections. Larvae were taken during most months, indicating that this species has a protracted spawning season in the Big Bend area. Seasonal distribution in the vicinity of the plant is illustrated in Figure 5.5. Although mean numbers per $100m^3$ were very low, it appears that two spawning peaks occurred during 1976, the first, larger peak from March through May, and the second much smaller peak from late August through December. Data from early 1977 indicates that spawning again increased during March.

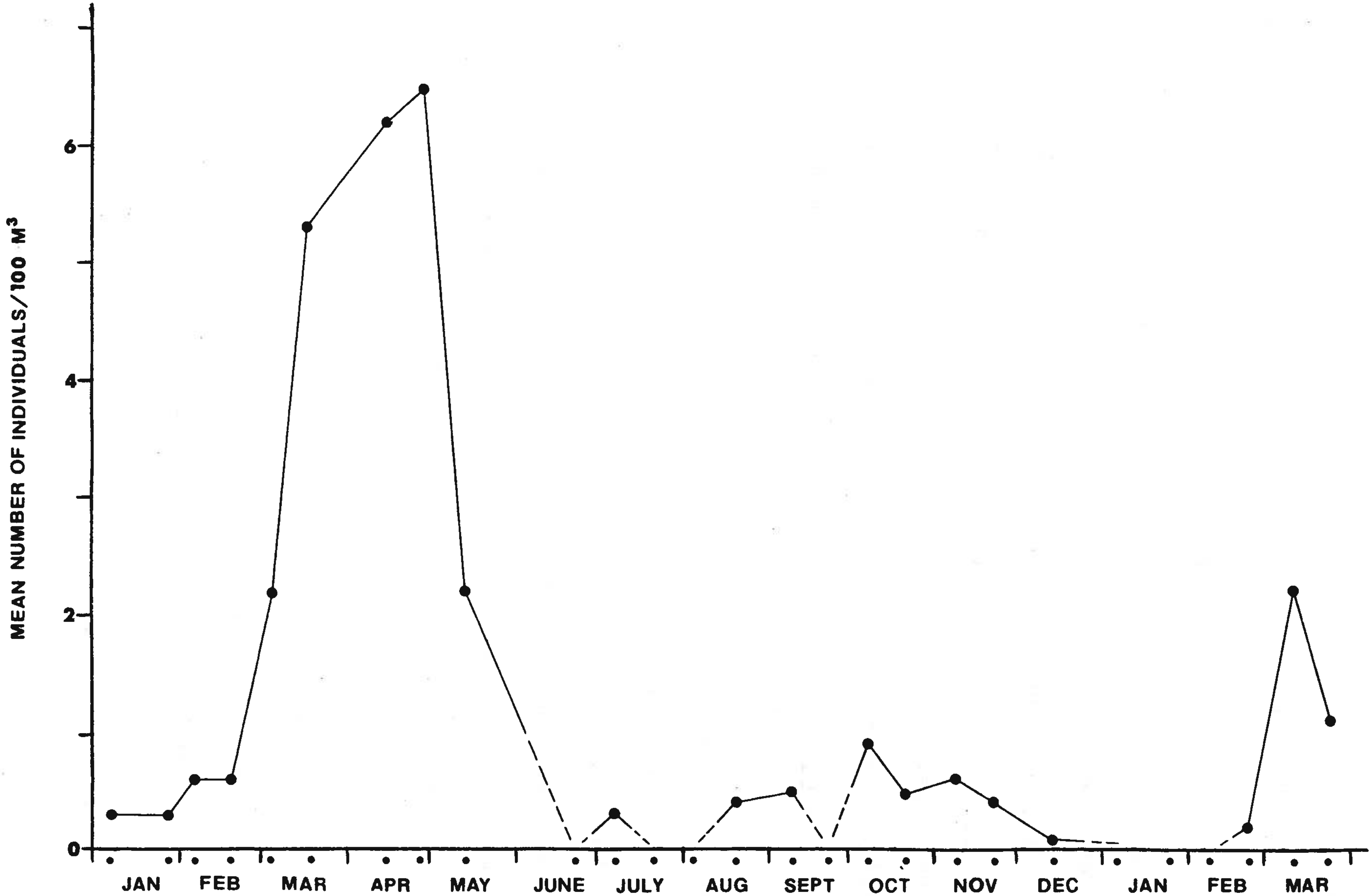


Figure 5.5. Seasonal abundance of <u>Gobiesox strumosus</u> larvae, January, 1976 - March, 1977.

It is obvious that any plant impact upon this species would be greatest during the spring.

CARANGIDAE - jacks and pompanos

Carangid eggs were taken on all sampling dates between April and early September. Three species of carangid eggs were identified, although only one of these was verified to species: _Oligoplites saurus_ (Bloch and Schneider), leather-jacket. Three species of carangid larvae were also present in samples collected between April and October including _O. saurus_, _Chloroscombrus chrysura_ (Linnaeus), and an unidentified member of the family. Figure 5.6 illustrates the seasonal distribution of eggs and larvae of the carangids grouped as a family. Eggs were most numerous on May 13, 1976, and there appears to be a second, smaller peak during July. Inexplicably low numbers of both eggs and larvae occurred on June 22 and August 3, 1976. It is unknown whether these low numbers indicate a cessation of spawning on these dates or whether they reflect sampling variability.

POMADASYIDAE - grunts

This family was represented in Big Bend ichthyoplankton by only one species, _Orthopristis chrysoptera_ (Linnaeus), the pigfish. Eggs of this species were not common, but were most abundant in early April, 1976. It is possible that the eggs

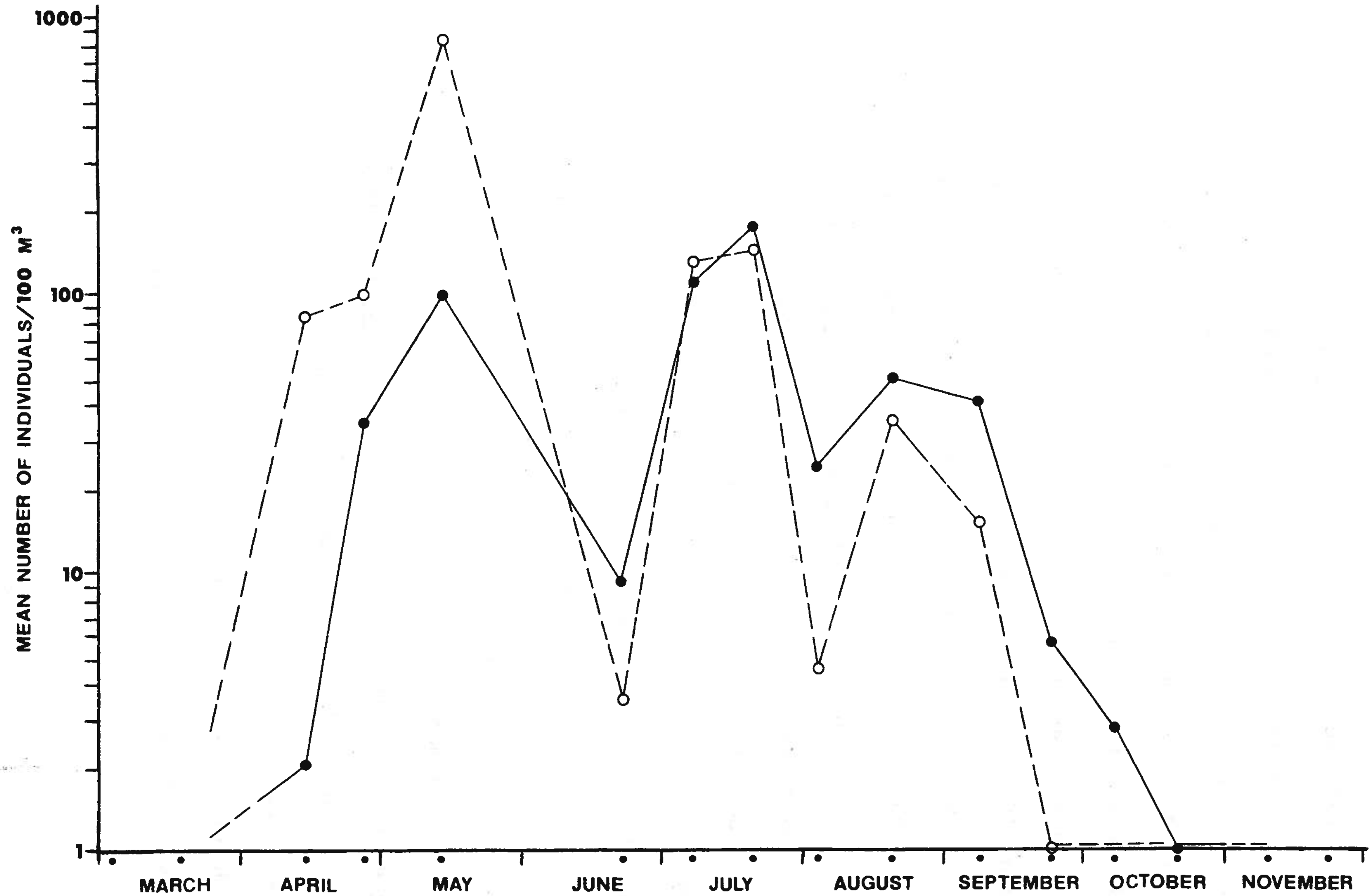


Figure 5.6. Seasonal abundance of carangid eggs (o---o) and larvae (●——●) during 1976.

of this species, at least in the early stages of development, were confused with sciaenid eggs. Larval pigfish were collected on all sampling dates between early April and early October, 1976. Peak densities occurred in early July, following a small peak in late April and low numbers during May. Hildebrand and Cable (1930) found that pigfish spawn between March and June at Beaufort, with peak spawning occurring in May. Springer and Woodburn (1960) did not capture ripe individuals during their study, but suggested that the spawning season in Tampa Bay parallels that at Beaufort, North Carolina. Because of the similarity between *O. chrysoptera* and *Bairdiella chrysura* larvae, it is possible that some of our smaller specimens may have been misidentified, which may partially explain this discrepancy.

A majority of the pigfish larvae taken at Big Bend were from stations near the plant rather than from open bay stations.

SPARIDAE - porgies

Larvae of two members of this family, *Archosargus probatocephalus* (Walbaum) the sheepshead and *Lagodon rhomboides* (Linnaeus), the pinfish, were present in ichthyoplankton collections. Eggs, if taken, were not recognized.

Sheepshead larvae were initially identified from a size series assembled from plankton catches. Our identification was confirmed by William Richards and Thomas Potthoff of the Southeast Fisheries Center, NMFS, Miami. No descriptions of this species were available at the time; however, larval stages have recently been described by Mook (1977).

A. probatocephalus larvae were collected from early April through early September. Peak densities occurred in late April and early May. Mean number of individuals per $100m^3$ by sampling date is illustrated in Figure 5.7. Springer and Woodburn (1960) attributed a spring spawning season to the species. No growth progression has been obtained from our data; however, small individuals (less than 2.5mm SL) were taken through the middle of August, indicating that, spawning was still occurring at that time.

Larval and early juvenile pinfish were collected only during January and February in both 1976 and 1977. Springer and Woodburn (1960) stated that this species spawns offshore in the Gulf during late fall and early winter, and the young move into Tampa Bay during the winter. Both Reid (1954) and Kilby (1955) found this was also true at Cedar Key. Most of the larvae taken at Big Bend were larger than 12.0mm SL confirming that they were spawned several weeks earlier. Pinfish were more numerous during 1977 than in 1976.

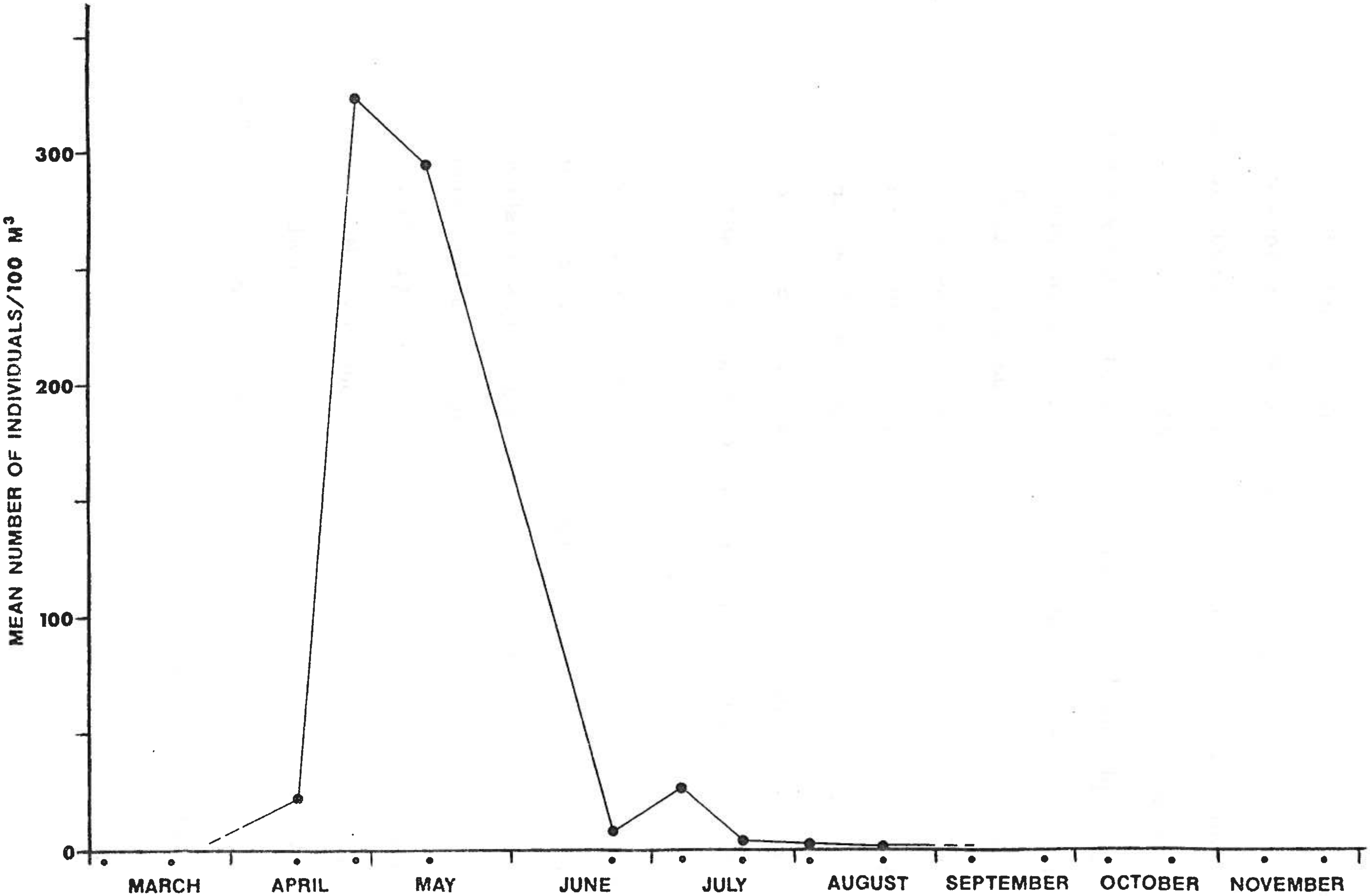


Figure 5.7. Seasonal abundance of _Archosargus probatocephalus_ (sheepshead) larvae during, 1976.

SCIAENIDAE - drums

Sciaenid eggs and larvae, as a family, were the second most abundant of all families collected during 1976. Only anchovies comprised a larger portion of the total number of eggs and larvae collected. Sciaenid eggs and larvae accounted for 26.2% and 3.9%, respectively, of all eggs and larvae taken.

Sciaenids were represented by a larger number of species (seven) than any other family. The seven species caught were: *Bairdiella chrysura* (Lacepede), silver perch; *Cynoscion arenarius* Ginsburg, sand seatrout; *C. nebulosus* (Cuvier), spotted seatrout; *Leiostomus xanthurus* Lacepede, spot; *Menticirrhus americanus* (Linnaeus), southern kingfish; *M. saxatilis* (Bloch and Schneider), northern kingfish; and *Pogonias cromis* (Linnaeus), black drum. Larval red drum, *Sciaenops ocellata* (Linnaeus) (locally called redfish) were not taken, or not recognized if taken.

The smaller eggs and larvae (smaller than 2.5mm SL) of sciaenids presented special problems in identification. Due to the similarity between many of the sciaenid species present in the area during these early stages, identifications below the family level may not always be accurate. In this report, neither seasonality nor entrainment will be discussed in terms of individual species. Instead, all species will be grouped and discussed as a family.

Several species of sciaenids, including the kingfishes, spotted seatrout and black drum are important commercial and sport fishes in the Tampa Bay area. Recreational fishermen frequently catch drums in the vicinity of the power plant, particularly during the late summer and in the fall.

Figure 5.8. shows the seasonal distribution of sciaenid eggs and larvae during 1976 and early 1977. Both eggs and larvae were present in relatively large numbers between early March and early November, 1976. Eggs were always more numerous than larvae, indicating a large amount of spawning was occurring within the study area. Neither eggs nor larvae were collected from late November, 1976 through January, 1977. Low numbers of eggs and larvae were taken during February, and numbers increased steadily through the final sampling date in March, 1977.

BLENNIIDAE - combtooth blennies

Most of the blenny larvae collected were identified as those of the feather blenny, _Hypsoblennius hentzi_ (Lesueur). Some of these larvae may be misidentified due to the similarity of larval _H. hentzi_ and another species common in Tampa Bay, _Chasmodes saburrae_ Jordan and Gilbert, the Florida blenny, whose larvae are undescribed. Another species, _H. ionthas_ (Jordan and Gilbert), the freckled blenny, may also occur in Tampa Bay. Because of this confusion, blennies will be discussed as a family.

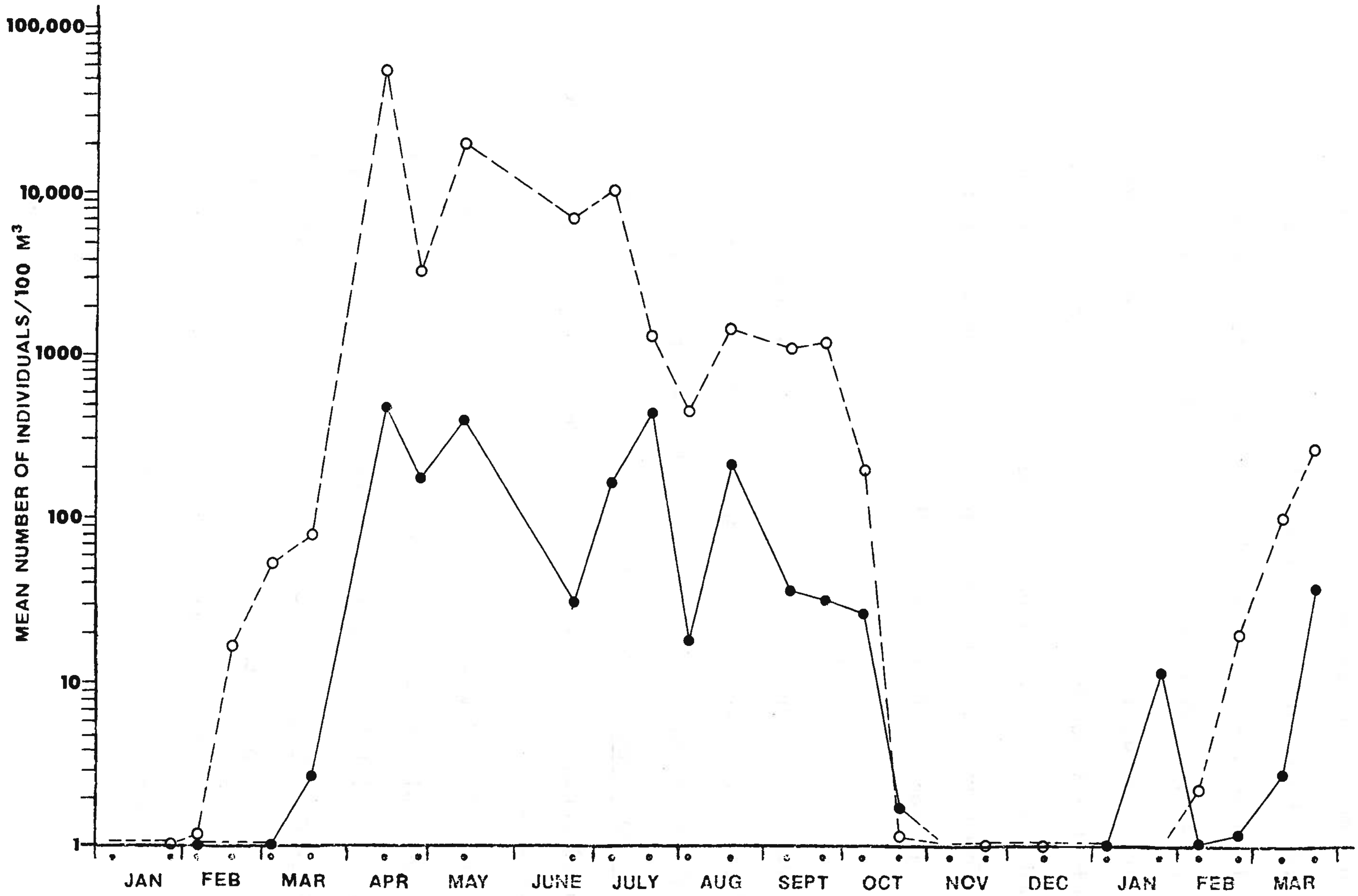


Figure 5.8. Seasonal abundance of sciaenid eggs (o---o) and larvae (●——●), January, 1976 - March, 1976.

Mean numbers of larvae per $100m^3$ by date are shown in Figure 5.9. Eggs, which are demersal, were never taken. Larval blennies were taken on all sampling dates except late February, 1977. Peak densities occurred from late April through early June, 1976. A second, smaller peak was evident from September through November, 1976. The number of larvae collected remained low throughout the winter months (December, 1976 to February, 1977) but the spring increase was again apparent in samples from March, 1977.

GOBIIDAE - gobies

Larval gobies are distinctive as a family and are easily identified at this level. The larvae of the two species of gobies which are common as adults in the Big Bend area, *Gobiosoma robustum* Ginsburg, the code goby, and *Microgobius gulosus* (Girard), the clown goby are undescribed. Other larvae of species of these two genera have been described by Hildebrand and Cable (1938); however, smaller larvae (less than 10mm SL) remain difficult to identify. Size series of larvae obtained from Big Bend ichthyoplankton collections verified the presence of both *G. robustum* and *M. gulosus* in the samples, but each genus is also represented by at least two other species in the Tampa Bay area (Springer and Woodburn, 1960; Springer, 1961). It is therefore possible that some of the smaller goby larvae

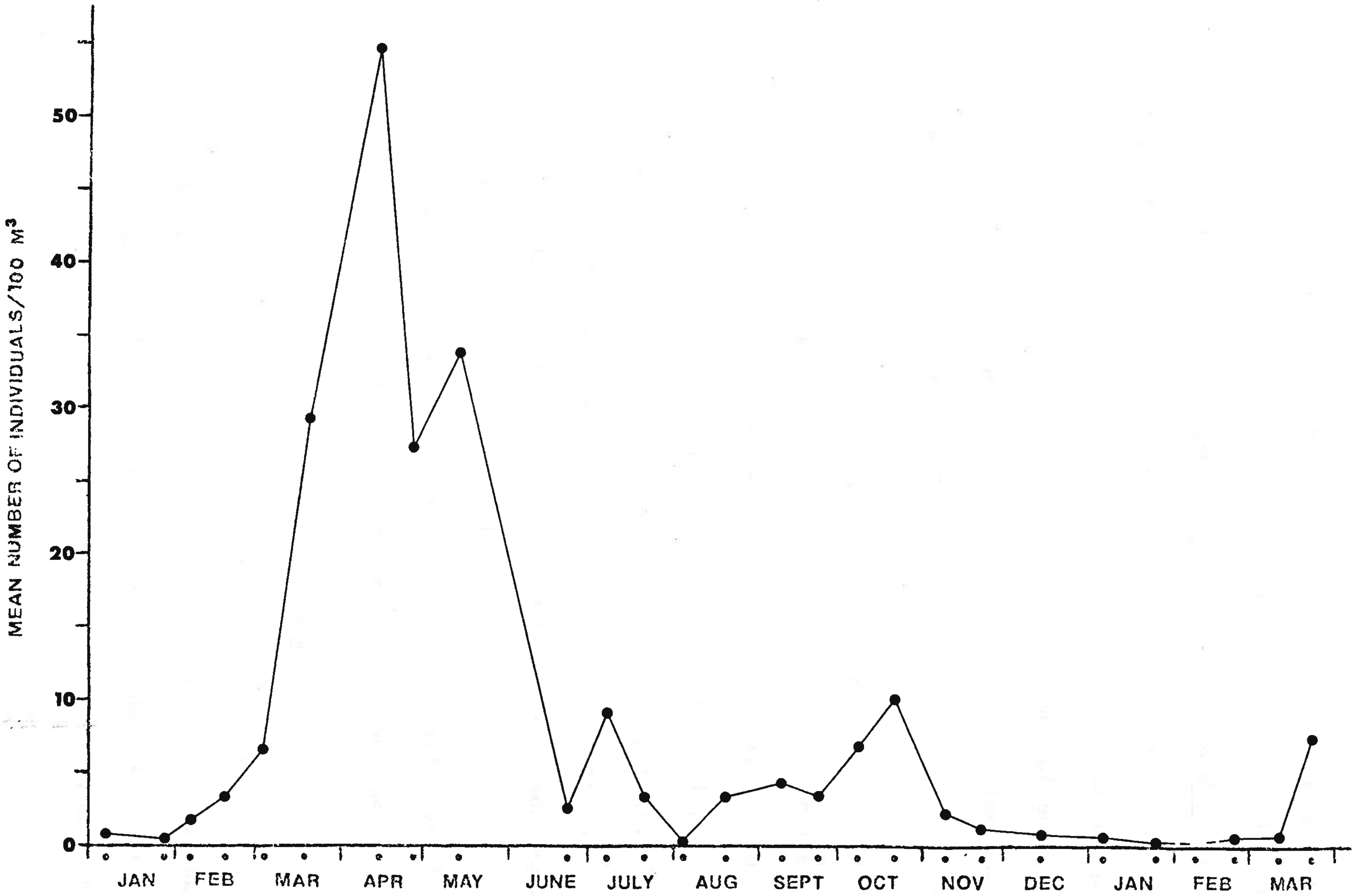


Figure 5.9. Seasonal abundance of blenny larvae, January, 1976 - March, 1977.

obtained at Big Bend were incorrectly identified. Between late February and the end of October, 1976, numerous specimens identified as ?Gobiosoma and ?Microgobius, both of which were described in a previous report (Phillips, 1976c), were obtained in plankton samples. It was not possible to assemble a size series for these larvae, because the largest individual collected was only 5.2mm SL. Goby eggs, which are demersal, were taken on only one occasion (March 3, 1976; plant discharge).

Seasonal data is presented in Figure 5.10. Gobies are treated as a family because of the identification problems discussed above. It appears that three peaks of abundance occurred during 1976, the first and largest in April. The second and third peaks, approximately equal in intensity but lower than the spring peak, occurred in late June through July, and from September through October. These two peaks may not actually be distinct, because the low number of larvae collected on August 3 may reflect either an actual decline in the amount of spawning or may reflect sampling variability.

SOLEIDAE - soles

Two species of soles were taken during routine ichthyoplankton sampling at Big Bend, viz., the lined sole *Achirus lineatus* (Linnaeus), and the hogchoker, *Trinectes maculatus* (Bloch and Schneider).

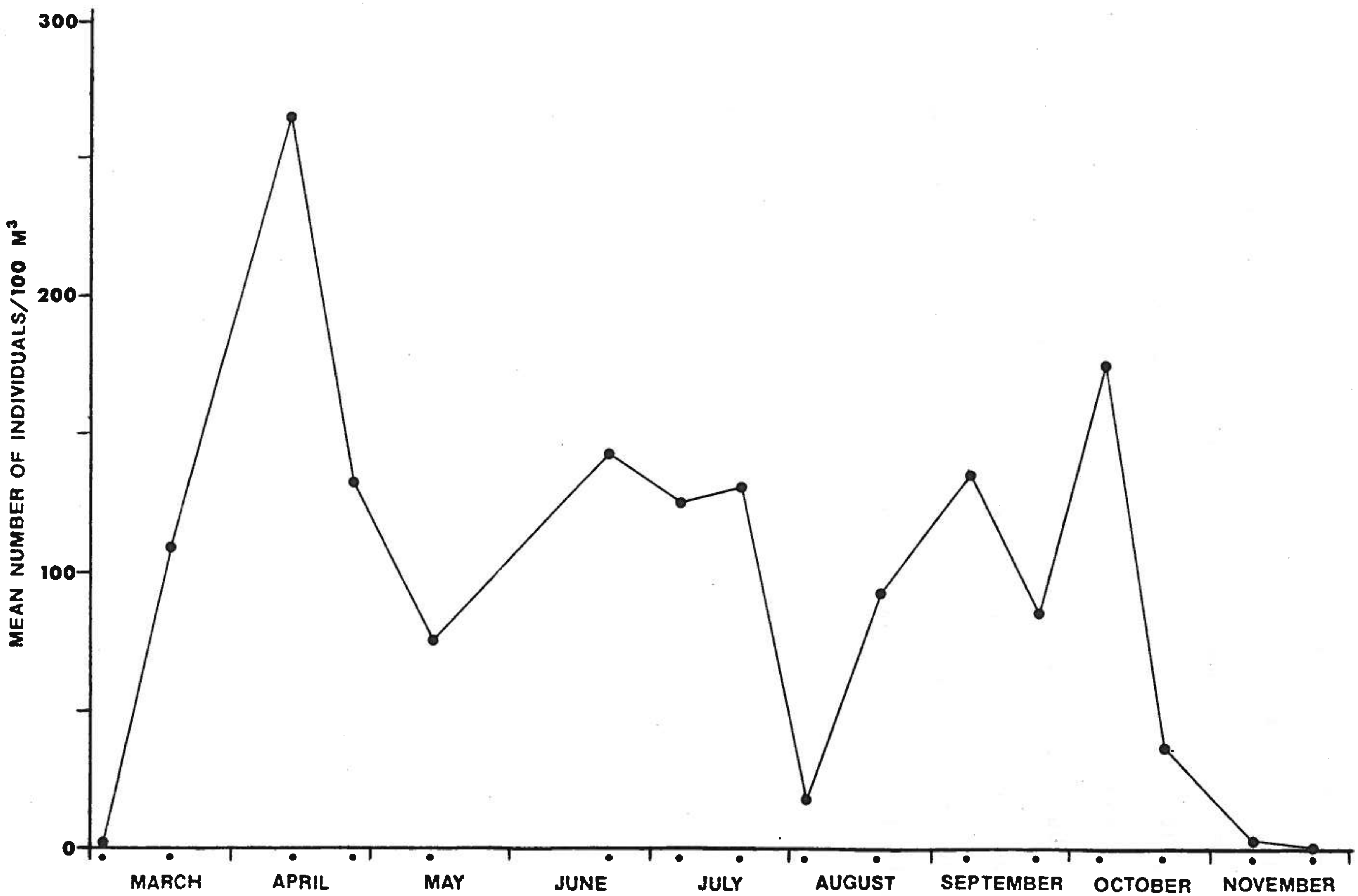


Figure 5.10. Seasonal abundance of goby larvae during 1976.

Hogchoker larvae were never common, but were collected in late April, during May, and again in July. *A. lineatus* larvae were present in low numbers from late April through early September, 1976, but no peaks in abundance were evident. As with many other species, samples from June 22 and August 3 contained the fewest larvae during this period although the reasons for this are not known. Houde, Futch, and Detwyler (1970) used Tampa Bay larvae collected between May and November 1962 and 1963 to describe development in this species.

Entrainment

Plant Operation

In order to calculate the numbers of eggs and larvae entrained by the plant during each month of the study, it is necessary to know the volume of water which passed through the plant during each month. Table 5.6 provides the number of days per month that each unit was in operation (circulating pump operation days). A constant volume of $15.21 m^3 sec^{-1}$ ($537 ft^3 sec^{-1}$) was assumed for each of the three units, based upon specifications outlined by Johnson (1977). A constant volume of $25.2 m^3 sec^{-1}$ ($83 ft^3 sec^{-1}$) was assumed for the dilution pump. Operational data for the plant circulating pumps and for the dilution pump was provided by Tampa Electric Company.

Calculations of Numbers Entrained

Estimated numbers of eggs and larvae entrained through the plant were calculated from data collected at the plant discharge (station I-1). Data collected at the plant intake (station I-6) was not used because of differences in sampling methodology. Samples were collected at station I-1 directly within the discharge flume. At station I-6, samples were collected in the normal fashion, by an oblique tow in the vicinity of the intake structure. Due to the nature of the two sampling methods,

Table 5.6. Plant and thermal pump operational data between January, 1976, and March, 1977 indicating the number of days each units were in operation.

Month	PLANT Unit 1	Unit 2	Unit 3	Total of All 3 Units	Dilution Pump
1976					
January	2.00	29.16	*	31.16	6.83
February	0.00	27.58	*	27.58	0.00
March	0.44	30.51	*	30.95	15.33
April	12.28	29.75	*	42.03	27.00
May	30.11	5.00	22.54	57.65	28.50
June	28.70	0.00	28.12	56.82	23.00
July	30.24	21.95	26.83	79.05	31.00
August	27.62	29.47	18.57	75.66	28.00
September	25.26	27.51	28.69	81.46	20.83
October	29.89	30.88	25.45	86.22	31.00
November	24.45	24.25	18.33	67.03	15.33
December	28.62	30.87	28.98	88.47	31.00
Total	239.61	286.93	197.51	724.05	257.82
1977					
January	29.41	25.95	27.73	83.09	27.83
February	27.69	25.93	15.04	68.66	22.83
March	30.20	30.67	0.00	60.87	26.83

* Not in Service

it appears that the samples taken at the discharge (station I-1) more accurately measure the ichthyoplankton entrainment through the plant. Entrainment of the eggs and larvae of each species collected was calculated according to the following formula:

$$E_x = P\,O_x \frac{A_d + A_n}{n}$$

E_x = estimated number of eggs or larvae entrained by the plant during period x

P = amount of water pumped through one unit per day (a constant equal to $1.314 \times 10^6 m^3$)

O_x = sum of the number of days each unit operated during period x

A_d = the number of individuals per m^3 collected at the plant discharge during the day during period x

A_n = the number of individuals per m^3 collected at the plant discharge during the night during period x

n = the number of sampling trips during period x (equal to 2, 1 day + 1 night)

Each sampling date is used to represent the period of time including one-half the number of days since the previous sampling date and one-half the number of days until the next sampling trip. For example, samples were collected on March 18, April 14 and April 27. The April 14 sampling date represents the period of time extending from April 1 through April 20.

After E_x was calculated for all of the time periods represented by sampling dates, the entrainment figures were summed to yield monthly entrainment figures. For example, the entrainment for the month of March, 1976, is equal to $\frac{23.5}{49}$ (entrainment for February 3.5 - March 23.5) + $\frac{7.5}{27.5}$ (entrainment for March 23.5 - April 20).

Estimated numbers of eggs and larvae entrained through the dilution pump were calculated from data collected at the pump intake (station 0-8) and the pump discharge (I-16). Since the collection methods at these two points were similar, an average of the numbers of each species collected at the two stations was used. Entrainment of the eggs and larvae of each species collected was calculated according to the following formula:

$$E_x = R\, D_x \frac{B_d + B_n}{n}$$

R = amount of water pumped through the dilution pump per day (a constant equal to $2.177 \times 10^6 m^3$)

D_x = the number of days the dilution pump operated during period x

B_d = an average of the number of individuals per m^3 collected at the dilution pump intake and discharge during the day during period x

B_n = an average of the number of individuals per m^3 collected at the dilution pump intake and discharge during the night during period x

n = the number of sampling trips during period x (equal to 2, 1 day + 1 night)

The dilution pumps stations (0-8 and I-16) were not sampled on several occasions due to construction or because the pumps were not operating. The period of time represented by certain sampling dates is, therefore, longer than was the case with the plant discharge, (station I-1). The estimates of dilution pump entrainment of eggs and larvae are, therefore, less accurate than the estimates of plant entrainment. The period of time from January 16 - March 15, 1976 is not represented by a sampling date. However, since the dilution pumps were not operating during this period, entrainment of eggs and larvae was equal to zero. To obtain the monthly entrainment figures, the entrainment for the various periods of time represented by each sampling date was summed as described for plant entrainment.

Estimated Entrainment

The estimated numbers of eggs and larvae of each species entrained monthly by both the dilution pump and the plant are presented in Appendices 5C 1-30. Entrainment figures were calculated for each species entrained. These figures must be used with caution. They represent the best estimates possible from the data collected, but are affected by sampling variability and species identification problems. The high coefficients of variation obtained for many species from the replicate tows taken during April, 1977 provide an indication of the possible sampling variability present throughout the study.

Discussion of entrainment will be limited to the eggs and larvae of a species of potential commercial importance, *Harengula jaguana*, the scaled sardine; a species important as a forage fish for other species in the area and which is also the most abundant species collected, *Anchoa mitchilli*, the bay anchovy; a family of importance as a sport fishery resource, the sciaenidae; and monthly totals of all species.

(i) Assessment of Entrainment of *Harengula jaguana* (scaled sardine)

The estimated numbers of scaled sardine eggs and larvae entrained by the dilution pumps and by the Big Bend plant between January, 1976 and March, 1977 are presented in Tables 5.7 and 5.8.

Eggs and larvae of *H. jaguana* were present in the vicinity of the plant and dilution pumps and susceptible to entrainment only between April and July, 1976. The greatest number of eggs

Table 5.7. Estimated number of *Harengula jaguana* eggs entrained by the Big Bend Plant and by the dilution pumps per month between January, 1976, and March, 1977.

Month	Number Entrained by Plant	Number Entrained by Dilution Pump	Total Number Entrained
1976			
January	0	0	0
February	0	0	0
March	0	0	0
April	1.719×10^{7}	3.983×10^{6}	2.117×10^{7}
May	5.113×10^{8}	8.232×10^{7}	5.936×10^{8}
June	2.980×10^{7}	8.958×10^{6}	3.876×10^{7}
July	4.186×10^{7}	4.923×10^{7}	9.109×10^{7}
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
TOTAL	6.002×10^{8}	1.445×10^{8}	7.446×10^{8}
1977			
January	0	0	0
Februrary	0	0	0
March	0	0	0

Table 5.8. Estimated number of *Harengula jaguana* larvae entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	0	0	0
March	0	0	0
April	3.948×10^6	1.945×10^5	4.142×10^6
May	3.352×10^6	4.019×10^6	7.371×10^6
June	1.342×10^6	7.575×10^6	8.917×10^6
July	1.629×10^7	3.524×10^7	5.153×10^7
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
Total	2.493×10^7	4.703×10^7	7.196×10^7
1977			
January	0	0	0
February	0	0	0
March	0	0	0

were entrained by both the plant and the dilution pumps during the month of May. Larvae were entrained in greatest numbers at both locations during the month of July. The number of eggs entrained by both the plant and the dilution pump was greater than the number of larvae entrained each month. Approximately four times as many eggs were entrained by the plant than by the dilution pumps. However, approximately twice as many larvae were entrained by the dilution pumps than by the plant. During 1976, a total of 7.466×10^8 eggs were estimated to be entrained by both the dilution pump and the plant. A total of 7.196×10^7 larvae were estimated to be entrained through the dilution pumps and the plant.

To assess the significance of the above entrainment estimates, it is necessary to estimate the number of eggs produced in the study area. This aspect is discussed in the following sections.

Size of Study Area and Number of Scaled Sardine Eggs Spawned

Each open bay station was used to represent a portion of the study area as shown in Figure 5.11. The area represented by each station is given in Table 5.9.

Determinations of the areas represented by each station were based upon known distances (in meters) between stations. Areas presented in Table 5.9 were used in Equation (1) to

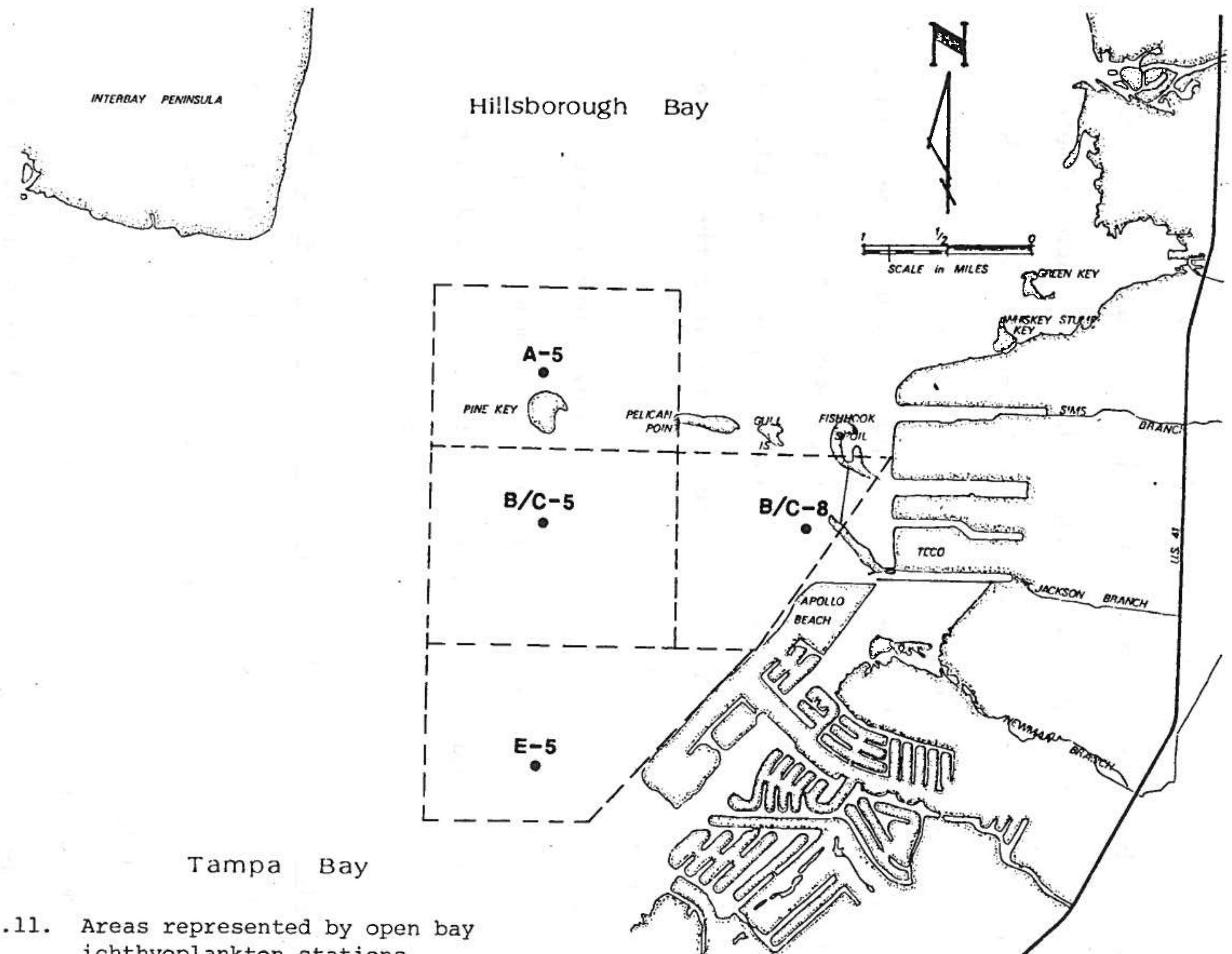


Figure 5.11. Areas represented by open bay ichthyoplankton stations.

Table 5.9. Area represented by each open bay ichthyoplankton station.

Station	Area Represented by Each Station ($m^2 \times 10^6$)
A-5	3.399
B/C-5	3.885
E-5	3.885
B/C-8	2.266

estimate the number of scaled sardine eggs spawned within the study area on each sampling date.

Number of Scaled Sardine Eggs in Study Area

The total number of *Harengula jaguana* eggs spawned within the study area during 1976 was calculated using techniques similar to those outlined by Sette and Ahlstrom (1948), Ahlstrom (1954, 1959) and Houde (1977).

The number of eggs collected at each station was used to estimate the total number of eggs in the area represented by each station. Areas represented by each station were calculated in square meters and were determined by the perpendicular bisectors of lines from each station to the adjacent station (except for station E-5 and B/C-8 where trapezoids were formed by the shoreline). The number of eggs within each area was determined from:

$$T_a = \frac{c_a d_a}{v_a} \cdot A_a \qquad (1)$$

Where T_a = the estimated total number of eggs in the area represented by station a.

c_a = catch at station a.

d_a = depth, in meters, at station a.

v_a = volume of water filtered at station a (cubic meters).

A_a = Area in square meters represented by station a.

The estimated number of eggs for the total study area represented by each biweekly sampling is:

$$T_k = \sum_{a=1}^{n} T_a \qquad (2)$$

Where T_k = the estimated number of eggs spawned within the study area on sampling date k.

n = the number of stations sampled on date k.

T_a = defined in Equation (1).

Estimated abundance of anchovy eggs within the study area during 1976 is calculated from:

$$T_y = \sum_{i=1}^{s} \frac{T_k \, D_k}{d_k} \qquad (3)$$

Where T_y = total estimated number of eggs spawned during the year.

s = the number of sampling days on which the estimate is based.

T_k = defined in Equation (2).

D_k = the number of days represented by sampling date k, equal to one half the days since the previous sampling and one half the days until the next sampling.

d_k = the duration (in days) of the egg stage from spawning until hatching.

Variance estimates on the abundance of eggs for each sampling date and for estimated total annual production were not calculated.

Impact Assessment

To estimate the impact of entrainment of eggs of *Harengula jaguana* by the plant and by the dilution pump, the number of eggs estimated to have been entrained is compared to the number of eggs estimated to have been produced within the study area. This method yields a percentage of eggs destroyed during the year as a result of the operation of the power plant (assuming 100% mortality of eggs passing through the plant).

This method does not address the possible impact of larval entrainment. Larval entrainment is more serious than a comparable amount of egg entrainment, due to the extremely high natural mortality rates between egg and early larval stages. There is no suitable method to estimate the impact of larval entrainment with the data available from the present study.

Estimates of the total number of *Harengula jaguana* eggs spawned in the study area on each sampling date are presented in Table 5.10. A total of 3.320×10^{11} eggs was estimated to have been produced during 1976 (April - July, 1976). The total number of eggs entrained by the combined action of the plant and the dilution pump was 7.446×10^{8}. The calculation:

Table 5.10. Annual spawning estimate for _Harengula jaguana_ within the open bay portion of the study area (based on stations B/C-8, A-5, B/C-5, and E-5) during 1976. Includes dates on which eggs were collected.

Date	Daily Spawning Estimate	# Days Represented By Each Sampling	Eggs Spawned During Each Sampling Period
April 14	4.707×10^{7}	20	9.414×10^{8}
April 27	2.850×10^{8}	14.5	4.133×10^{9}
May 13	8.173×10^{8}	28	2.288×10^{10}
June 22	8.301×10^{9}	27.5	2.283×10^{11}
July 7	6.378×10^{8}	14	8.929×10^{9}
July	4.948×10^{9}	13.5	6.680×10^{10}
		Total	3.320×10^{11}

$$\frac{\#\text{ eggs entrained}}{\#\text{ eggs produced}} \times 100\% = \%\text{ of eggs produced destroyed by}$$

entrainment.

This calculation yields an estimate that 0.22% of the scaled sardine eggs in the study area were destroyed as a result of entrainment resulting from plant operation during 1976.

(ii) Assessment of Entrainment of *Anchoa mitchilli* (bay anchovy)

The estimated number of *A. mitchilli* eggs and larvae entrained by the dilution pumps and by the plant between January, 1976 and March, 1977 are presented in Tables 5.11 and 5.12.

Eggs or larvae were entrained by the dilution pumps and/or the plant during all months except January and December, 1976 and January, 1977. The highest number of eggs were entrained by both the dilution pump and by the plant during the month of May. Entrainment of eggs during 1976 at both locations increased steadily to a maximum point during May, then decreased steadily until eggs were no longer present. Entrainment of eggs during 1976 was approximately equal at the dilution pumps and the plant, resulting in a total of 5.795×10^{10} eggs estimated to have been entrained during the year. The highest number of larvae were entrained by the plant during the month of August, and by the dilution pump during the month of May.

Table 5.11. Estimated number of *Anchoa mitchilli* eggs entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	2.582×10^7	0	2.582×10^7
March	2.398×10^8	3.757×10^9	3.997×10^9
April	9.579×10^9	7.245×10^9	1.682×10^{10}
May	1.350×10^{10}	1.141×10^{10}	2.491×10^{10}
June	3.429×10^9	3.168×10^9	6.597×10^9
July	1.673×10^9	3.414×10^9	5.087×10^9
August	1.613×10^8	1.960×10^8	3.573×10^8
September	9.298×10^7	3.338×10^7	1.264×10^8
October	2.672×10^7	0	2.672×10^7
November	0	0	0
December	0	0	0
Total	2.873×10^{10}	2.922×10^{10}	5.795×10^{10}
1977			
January	0	0	0
February	0	1.306×10^5	1.306×10^5
March	1.362×10^{10}	6.885×10^9	2.050×10^{10}

Table 5.12. Estimated number of *Anchoa mitchilli* larvae entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	0	0	0
March	1.949×10^6	1.659×10^9	1.661×10^9
April	4.614×10^9	3.044×10^9	7.658×10^9
May	3.950×10^9	1.828×10^9	5.778×10^9
June	9.439×10^8	4.089×10^8	1.353×10^9
July	4.197×10^9	2.901×10^9	7.098×10^9
August	5.934×10^9	5.426×10^8	6.477×10^9
September	2.902×10^9	2.103×10^8	3.112×10^9
October	3.689×10^8	1.487×10^7	3.837×10^8
November	8.343×10^5	1.447×10^6	2.281×10^6
December	0	0	0
Total	2.291×10^{10}	1.061×10^{10}	3.352×10^{10}
1977			
January	0	0	0
February	0	0	0
March	1.036×10^9	2.578×10^8	1.294×10^9

A total of 3.352×10^{10} larvae were estimated to have been entrained by both the plant and the dilution pump during 1976.

Impact Assessment

The total number of *Anchoa mitchilli* eggs spawned within the study area was calculated using the method described for *Harengula jaguana* eggs.

Estimates of the total number of *A. mitchilli* eggs spawned on each sampling date and the number of days represented by each date are presented in Table 5.13. Months during which no anchovy eggs were collected (January, February and December, 1976) were omitted from the table. Daily spawning estimates were derived from Equations (1) and (2).

The total number of anchovy eggs spawned during 1976 was derived with Equation (3). A value of one was used for the duration in days of the egg stage [denominator of Equation (3)] based upon information given by Mansueti and Hardy (1967).

Based upon Big Bend ichthyoplankton catches, it is estimated that 2.688×10^{12} *A. mitchilli* eggs were spawned in the open bay portion of the study area during 1976.

A total of 5.795×10^{10} *A. mitchilli* eggs were estimated to have been entrained during 1976 by the combined operation of the dilution pump and the plant. The eggs entrained represent only 2.16% of the total eggs estimated to occur in the open bay

Table 5.13. Annual spawning estimate for *A. mitchilli* within open bay portion of study area (based on stations B/C-8, A-5, B/C-5, and E-5) during 1976. Includes only dates on which eggs were collected.

Date	Daily Spawning Estimate (eggs x 10^8)	Days Represented By Each Sampling	Eggs Spawned During each Sampling Period (x 10^{10})
Feb. 18	0.0795	13	0.0103
Mar. 3	20.7327	14.5	3.0062
Mar. 18	48.0539	21	10.0913
Apr. 14	350.0635	20	70.1269
Apr. 27	162.9718	14.5	23.6309
May 13	38.7373	28	10.8465
June 22	190.0147	27.5	52.2540
July 7	359.7119	14	50.3597
July 20	50.9364	13.5	6.8764
Aug. 3	74.1741	14.5	10.7553
Aug. 18-19	37.5937	18	6.7669
Sept. 8	61.2089	18	11.0176
Sept. 22	12.1789	14.5	1.7659
Oct. 7	80.8753	14	11.3225
Nov. 9	0.0051	16	0.0008
Nov. 22	0.0071	18.5	0.0013
		Total	268.8327

portion of the study area. It does not appear that this level of entrainment of anchovy eggs would have a significant effect on the adult anchovy population in the study area.

Even though a considerable amount of data has been gathered on this species as part of the ichthyoplankton program at Big Bend, the population dynamics of Tampa Bay anchovies remain relatively unknown. Gunter (1945), Reid (1954) and Kilby (1955) suggested that this species primarily inhabited open bays in Taxas and at Cedar Key. Past trawling studies at Big Bend neither confirm nor deny this pattern in Tampa Bay; however, large schools have been observed near open bay stations during the spring and summer months. Ichthyoplankton collections indicate that the majority of the spawning in this species does occur at open bay stations, which limits the potential entrainment of eggs. Data gathered as part of the adult fish surveys at Big Bend suggest that juvenile anchovies move inshore (where they are taken in seine hauls and on the travelling screens) during the late fall, and remain there throughout the winter months.

(iii) Entrainment of Sciaenidae - drums

Seven species of sciaenid larvae were recognized from samples collected during the course of this study. Eggs were less recognizable and were separated into three genera, plus a large number that could not be identified. Because of these identification problems with the eggs and smaller larvae, discussion of sciaenid eggs and larvae will be limited to a treatment of the family as a whole. Entrainment of individual species is listed for each month in Appendix 5C, but these estimates are less reliable than those of other more readily identifiable species.

The estimated numbers of sciaenid eggs and larvae entrained by the dilution pumps and the plant between January, 1976 and March, 1977 are presented in Tables 5.14 and 5.15.

Sciaenid eggs were entrained during all months except January, 1976. Larvae were entrained during all months except January, February, November and December, 1976. The highest numbers of sciaenid eggs were entrained during the month of April at both the dilution pump and the plant. The number of eggs entrained during 1976 increased to a peak during the month of April, then steadily decreased to a minimum during the month of December. The highest number of larvae were entrained by the plant during the month of April and by the dilution pump during the month of May. A total of 1.255×10^{11} eggs and 1.269×10^{9} larvae were entrained during 1976 by both the dilution pump and the plant.

Table 5.14. Estimated number of Sciaenidae eggs entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	4.471×10^{6}	0	4.471×10^{6}
March	3.062×10^{7}	1.438×10^{10}	1.441×10^{10}
April	3.024×10^{6}	2.661×10^{10}	5.685×10^{10}
May	1.863×10^{10}	2.028×10^{10}	3.891×10^{10}
June	3.490×10^{9}	4.582×10^{9}	8.072×10^{9}
July	2.681×10^{9}	3.468×10^{9}	6.149×10^{9}
August	4.316×10^{8}	1.601×10^{8}	5.917×10^{8}
September	1.854×10^{8}	3.272×10^{7}	2.181×10^{8}
October	1.779×10^{7}	0	1.779×10^{7}
November	9.646×10^{5}	8.172×10^{4}	1.046×10^{6}
December	2.994×10^{5}	1.532×10^{4}	3.147×10^{5}
Total	5.571×10^{10}	6.951×10^{10}	1.252×10^{11}
1977			
January	0	3.581×10^{4}	3.581×10^{4}
February	1.648×10^{6}	3.979×10^{6}	5.627×10^{6}
March	5.587×10^{7}	3.856×10^{7}	9.443×10^{7}

Table 5.15. Estimated number of Sciaenidae larvae entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	0	0	0
March	2.784×10^5	8.110×10^7	8.137×10^7
April	1.837×10^8	1.530×10^8	3.367×10^8
May	1.339×10^8	1.758×10^8	3.097×10^8
June	3.508×10^7	3.733×10^7	7.241×10^7
July	1.083×10^8	1.538×10^8	2.621×10^8
August	1.138×10^8	3.164×10^7	1.454×10^8
September	4.094×10^7	1.262×10^7	5.356×10^7
October	5.852×10^6	1.792×10^6	7.644×10^6
November	0	0	0
December	0	0	0
Total	6.219×10^8	6.471×10^8	1.269×10^9
1977			
January	2.437×10^6	3.581×10^4	2.473×10^6
February	1.171×10^6	1.909×10^5	1.362×10^6
March	7.511×10^6	4.546×10^6	1.206×10^7

Impact Assessment

The number of sciaenid eggs produced within the study area was not calculated for individual species. It was not possible to identify sciaenid eggs accurately enough to utilize this method of estimating the number of eggs produced within the study area during 1976. As a result, the impact of the entrainment of sciaenid eggs can not be accurately assessed.

The assessment of the entrainment of sciaenid eggs as a group would not be biologically valid due to possible differences in spawning habits and population levels of the various species in the study area.

(iv) Total Eggs and Larvae

The estimated total number of eggs and larvae of all species entrained by the dilution pumps and the plant between January, 1976 and March, 1977 are presented in Tables 5.16 and 5.17.

Eggs were entrained during every month except January, 1976. Larvae were entrained during every month. The highest number of eggs were entrained by both the dilution pump and by the plant during the month of April. Entrainment of eggs during 1976 increased to a peak value during the month of April, then declined monthly throughout the remainder of the year. Egg entrainment remained at a high level from March - July. The highest number

Table 5.16. Estimated number of total eggs entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Operating Days By Plant	# Entrained By Dilution Pump	# Operating Days By Dilution Pump	Total # Entrained
1967					
January	0	31.16	0	6.83	0
February	3.069×10^7	27.58	0	0	3.069×10^7
March	2.709×10^8	30.95	1.817×10^{10}	15.33	1.845×10^{10}
April	3.996×10^{10}	42.03	3.395×10^{10}	27	7.391×10^{10}
May	3.295×10^{10}	57.65	3.246×10^{10}	28.5	6.541×10^{10}
June	7.092×10^9	56.82	8.126×10^9	23	1.522×10^{10}
July	4.442×10^9	79.05	7.029×10^9	31	1.147×10^{10}
August	6.052×10^8	75.66	3.599×10^8	28	9.652×10^8
September	2.803×10^8	81.46	6.689×10^7	20.83	3.472×10^8
October	4.592×10^7	86.22	0	31	4.592×10^7
November	9.646×10^5	67.03	8.172×10^4	15.33	1.046×10^6
December	2.994×10^5	88.47	1.532×10^4	31	3.147×10^5
Total	8.568×10^{10}	724.05	1.002×10^{11}	257.82	1.858×10^{11}
1977					
January	0	83.09	3.581×10^4	27.83	3.581×10^4
February	1.648×10^6	68.66	4.110×10^6	22.83	5.758×10^6
March	1.368×10^{10}	60.87	6.925×10^9	26.83	2.060×10^{10}

Table 5.17. Estimated number of total larvae entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Operating Days By Plant	# Entrained By Dilution Pump	# Operating Days By Dilution Pump	Total # Entrained
1976					
January	2.217×10^6	31.16	5.940×10^5	6.83	2.811×10^6
February	3.022×10^6	27.58	0	0	3.022×10^6
March	5.342×10^7	30.95	1.873×10^9	15.33	1.926×10^9
April	5.234×10^9	42.03	3.458×10^9	27	8.692×10^9
May	4.476×10^9	57.65	2.502×10^9	28.5	6.949×10^9
June	1.161×10^9	56.82	5.926×10^8	23	1.754×10^9
July	4.764×10^9	79.05	3.197×10^9	31	7.961×10^9
August	6.290×10^9	75.66	6.325×10^8	28	6.923×10^9
September	3.434×10^9	81.46	2.939×10^8	20.83	3.728×10^9
October	6.191×10^8	86.22	3.266×10^7	31	6.517×10^8
November	1.312×10^7	67.03	6.136×10^6	15.33	1.926×10^7
December	1.871×10^6	88.47	2.007×10^6	31	3.878×10^6
Total	2.596×10^{10}	724.05	1.259×10^{10}	257.82	3.855×10^{10}
1977					
January	2.437×10^6	83.09	2.937×10^6	27.83	5.374×10^6
February	6.914×10^6	68.66	4.829×10^6	22.83	1.174×10^7
March	1.087×10^9	60.87	2.756×10^8	26.83	3.843×10^8

of larvae were entrained by the plant during the month of August, and by the dilution pump during the month of April. Larval entrainment remained at a high level between March and October. A total of 1.858×10^{11} eggs and 3.855×10^{10} larvae were entrained during 1976 by the combined operation of the plant and the dilution pump.

SUMMARY AND CONCLUSIONS

1. Larvae of forty-one species representing twenty-two families were collected during Big Bend ichthyoplankton studies. Eggs from twelve families were also collected.
2. Spawning occurred during all months between January, 1976 and March, 1977. Peak densities of both eggs and larvae occurred during spring and summer months. The least amount of spawning activity occurred during winter months of both 1976 and 1977.
3. Eggs and larvae of the bay anchovy, *Anchoa mitchilli*, were more abundant than any other species during the spring and summer. Engraulids accounted for 73.1% of all eggs and 87.4% of all larvae collected during the fifteen months. The spawning season at Big Bend began in early March, 1976 and continued through late October, 1976.
4. Sciaenids, represented by seven species of larvae, were second in abundance after the engraulids, making up 26.2% of all eggs and 3.9% of all larvae collected during the study. Sciaenid eggs and larvae were present within the study area between early March and early November, 1976.

5. Larval clupeids, carangids, pomadasyids, sparids and gobiids were also common in spring and summer samples, although each family made up less than 3% of all larvae collected.

6. Winter samples were dominated by blenny and goby larvae, but numbers were usually low. Pinfish, menhaden, and spot larvae migrated into the study area from spawning grounds offshore during January and February of both 1976 and 1977.

7. It is estimated that a total of 1.858×10^{11} eggs and 3.855×10^{10} larvae were entrained by the plant during 1976. Egg entrainment occurred during all months except January, 1976. Larvae were entrained during every month of the study. The greatest amount of both egg and larval entrainment occurred in April, 1976.

8. Total sciaenid entrainment (seven species) during 1976 was estimated to be 1.252×10^{11} and 1.269×10^{9} for eggs and larvae, respectively. The significance of this amount of entrainment could not be evaluated due to the problems encountered in identifying the individual species.

9. _H. jaguana_ entrainment occurred during the months of April through July, 1976. The estimated number of entrained eggs was 7.446×10^{8}. Larval entrainment was

estimated to be 7.196×10^7 individuals.

10. The number of *H. jaguana* eggs entrained was estimated to represent 0.22% of the eggs produced in the open bay portion of the study area.

11. Entrainment of *A. mitchilli* eggs occurred from February - October, 1976 and in March, 1977. Larvae were entrained from March - December, 1976 and in March, 1977. Estimated numbers entrained during 1976 were 5.795×10^{10} eggs and 3.352×10^{10} larvae.

12. The number of *A. mitchilli* eggs entrained was estimated to represent 2.16% of the eggs produced in the open bay portion of the study area.

13. The impact of entrainment of larvae was not assessed due to the absence of a suitable method.

LITERATURE CITED

Ahlstrom, E. H. 1954. Distribution and abundance of egg and larval populations of the Pacific sardine. U.S. Fish Wildl. Serv., Fish. Bull. 56:83-140.

Ahlstrom, E. H. 1959. Distribution and abundance of eggs of the Pacific sardine, 1952-1956. U.S. Fish Wildl. Serv., Fish. Bull. 60:185-213.

Atomic Energy Commission. 1973. Final environmental statement. Shoreham nuclear power station.

Austin, H. M. 1973. The ecology of Lake Montauk: planktonic fish eggs and larvae. N.Y. Ocean Sci. Lab. Tech. Rep. No. 0021. 37 p.

Barkley, R. A. 1972. Selectivity of towed net samplers. U.S. Nat. Mar. Fish. Serv., Fish. Bull. 70(3): 799-820.

Bridger, J. P. 1956. On day and night variation in catches of fish larvae. J. du Cons. 22(1):42-57.

Carr, W. E. S. and J. T. Giesel. 1975. Impact of thermal effluent from a steam-electric station on a marshland nursery area during the hot season. Fish. Bull. 73(1):67-80.

Clark, J. and W. Brownell. 1973. Electric power plants in the coastal zone: environmental issues. Amer. Littoral Soc. Spec. Publ. No. 7 125 p.

Clark, J., W. G. Smith, A. W. Kendall, Jr. and M. P. Fahay. 1969. Studies of estuarine dependence of Atlantic coastal fishes. Data report I: northern section: Cape Cod to Cape Lookout. R. V. Dolphin cruises 1965-1966: zooplankton volumes, midwater trawl collections, temperatures and salinities. U.S. Fish Wildl. Serv., Tech. Rep. 28. 132 p.

Clark, J., W. G. Smith, A. W. Kendall, Jr. and M. P. Fahay. 1970. Studies of estuarine dependence of Atlantic coastal fishes. Data Report II: southern section: New River Inlet, North Carolina, to Palm Beach, Florida. R.V. Dolphin cruises 1966-68: zooplankton volumes, surface-meter net collections, temperatures, and salinities. U.S. Fish Wildl. Serv., Tech. Pap. 59. 97 p.

Clutter, R. I. and M. Anraku. 1968. Avoidance of samplers. In: Zooplankton sampling. D. J. Tranter (ed.). UNESCO monograph on oceanographic methodologies No. 2. 174 p.

Conservation Consultants, Inc. 1975. Prospectus for ecological studies at Big Bend Steam Electric Station (Tampa Electric Company) - a 316 demonstration. 101 p.

Coutant, C. C. 1974. Opening remarks at Entrainment and Intake Screening Workshop: "Evaluation of entrainment effects". p. 1-11. In: L. D. Jensen (ed.). Entrainment and Screening: Proceedings of the Second Entrainment and Screening Workshop. Cooling Water Studies for Electric Power Research Institute, Rep. No. 15. 347 p.

Cushing, D. H. 1962. Patchiness. Rapp. Proc. Verb. Int. Cons. Explor. Mer 153:152-164.

Dahlberg, M. D. 1970. Atlantic and Gulf of Mexico menhadens, genus Brevoortia (Pisces:Clupeidae). Bull. Fl. State Mus. 15(3):91-162.

DeSylva, D. P. 1969. Theoretical considerations of the effects of heated effluents on marine fishes. In: P. A. Krenkel and F. L. Parker (eds.). Biological Aspects of Thermal Pollution. Vanderbilt Press, Nashville, Tenn., p. 229-293.

DeSylva, D. P. 1970. Ecology and distribution of postlarval fishes of southern Biscayne Bay, Florida. Progress Report to EPA. 198 p.

Eberhardt, L. L. and R. O. Gilbert. 1975. Biostatistical aspects. In: National Environmental Studies Project. Environmental Impact Monitoring of Nuclear Power Plants. Source Book of Monitoring Methods, Vol. 2: 783-918.

Edsall, T. A. and T. G. Yocum. 1972. Review of recent technical information concerning the adverse effects of once-through cooling on Lake Michigan. U.S. Fish Wildl. Serv., Bur. Sport Fish. and Wildl., Great Lakes Fish. Lab., Ann Arbor, Michigan. 86 p.

Florida Power Corporation. 1975. Summary, analysis and supplementary data. Report to the Interagency Research Advisory Committee.

Fore, P. L. and K. N. Baxter. 1972. Diel fluctuations in the catch of larval Gulf menhaden, *Brevoortia patronus*, at Galveston Entrance, Texas. Trans. Amer. Fish. Soc. 101(4):729-732.

Gallaway, B. J. & K. Strawn. 1974. Seasonal abundance and distribution of marine fishes at a hot-water discharge in Galveston Bay, Texas. Mar. Sci. 18:71-137.

Gunter, G. 1945. Studies on marine fishes of Texas. Publ. Inst. Mar. Sci. 1(1):1-190.

Hildebrand, S. F. and L. E. Cable. 1930. Development and life history of fourteen teleostean fishes at Beaufort, North Carolina. U.S. Bur. Fish., Bull. 46:383-488.

Hildebrand, S. F. and L. E. Cable. 1938. Further notes on the development and life history of some teleosts at Beaufort, North Carolina. U. S. Bur. Fish., Bull. 48 (24): 505-642.

Houde, E. D. 1977. Abundance and potential yield of the round herring, *Etrumeus teres*, and aspects of its early life history in the eastern Gulf of Mexico. Fish. Bull. 75 (1): 61-89.

Houde, E. D., C. R. Futch, and R. Detwyler. 1970. Development of the lined sole, *Achirus lineatus*, described from laboratory reared and Tampa Bay specimens. Fla. Dept. Nat. Resour. Mar. Res. Lab., Tech. Ser. No. 62. 43 p.

Johnson, W. J. 1977. Thermal impact reduction by dilution Big Bend Station, Tampa, Florida. Unpubl. Ms. 12 p.

Kelly, J. A. and A. Dragovich. 1967. Occurrence of macrozooplankton in Tampa Bay, Florida and the adjacent Gulf of Mexico. NOAA Fish. Bull. 66(2):209-221.

Kilby, J. D. 1955. The fishes of two Gulf coastal marsh areas of Florida. Tulane Stud. Zool. 2(8):175-247.

Mahnken, C.V.W. and J. W. Jossi. 1967. Flume experiments on the hydrodynamics of plankton nets. J. Cons. Perm. Int. Explor. Mer 31 (1): 38-45.

Mansueti, A. J. and J. D. Hardy, Jr. 1967. Development of fishes of the Chesapeake Bay region: An atlas of egg, larval, and juvenile stages. Nat. Resour. Inst. Univ. Maryland, Port City Press, Baltimore, Md., 202 p.

Marcy, B. C., Jr. 1971. Survival of young fish in the discharge canal of a nuclear power plant. J. Fish. Res. Bd. Canada 28:1057-1060.

Marcy, B. C., Jr. 1973. Vulnerability and survival of young Connecticut River fish entrained at a nuclear power plant. J. Fish. Res. Bd. Canada 30(8):1195-1203.

Marcy, B. C., Jr. 1974. Entrainment of organisms at power plants, with emphasis on fishes - an overview. In: S.B. Saila (ed.). Fisheries and Energy Production: a symposium. D. C. Heath and Co., Lexington, Mass.

Martinez, S. and E. D. Houde. 1975. Fecundity, sexual maturation, and spawning of scaled sardine (*Harengula jaguana* Poey). Bull. Mar. Sci. 25 (1):35-45.

Mayer, A. G. 1914. The effects of temperature upon tropical marine animals. Pap. Tortugas Lab. 6(1):1-24.

Mihursky, J. A. 1969. Patuxent thermal studies - summary and recommendations. Univ. of Maryland Nat. Res. Inst., Spec. Rep. No. 1.

Moe, M. A., Jr. and G. T. Martin. 1965. Fishes taken in monthly trawl samples offshore of Pinellas County, Florida, with new additions to the fish fauna of the Tampa Bay area. Tulane Stud. Zool. 12(4): 129-151.

Mook, D. 1977. Larval and osteological development of the sheepshead, *Archosargus probatocephalus* (Pisces: Sparidae). Copeia 1977 (1):126-133.

Morgan, R. P. III, and R. G. Stross. 1969. Destruction of phytoplankton in the cooling water supply of a steam electric station. Ches. Sci. 10(3-4):165-171.

Pearse, A. A. and G. Gunter. 1957. Salinity. In: J. W. Hedgepeth (ed.). Treatise on Marine Ecology and Paleoecology. Mem. 67. Geol. Soc. Amer. p. 129-157.

Phillips, T. D. 1976a. Ichthyoplankton studies, Chapter 5. In: Tampa Electric Company, Twenty-fifth Quarterly Report on the Big Bend thermal and Ecological Surveys. Contains the Twenty-second Quarterly Report by Conservation Consultants, Inc. R. Garrity, ed. 346 p.

Phillips, T. D. 1976b. Ichthyoplankton studies, Chapter 5. In: Tampa Electric Company, Twenty-sixth Quarterly Report on the Big Bend thermal and Ecological Surveys. Contains the Twenty-third Quarterly Report by Conservation Consultants, Inc. R. Garrity, ed. 469 p.

Phillips, T. D. 1976c. Ichthyoplankton studies, Chapter 5. In: Tampa Electric Company, Twenty-seventh Quarterly Report on the Big Bend thermal and Ecological Surveys. Contains the Twenty-fourth Quarterly Report by Conservation Consultants, Inc. R. Garrity, ed. 440 p.

Phillips, T. D. 1977a. Ichthyoplankton studies, Chapter 5. In: Tampa Electric Company, Twenty-eighth Quarterly Report on the Big Bend thermal and Ecological Surveys. Contains the Twenty-fifth Quarterly Report by Conservation Consultants, Inc. R. Garrity, ed. 651 p.

Phillips, T. D. 1977b. Ichthyoplankton studies, Chapter 5. In: Tampa Electric Company, Twenty-ninth Quarterly Report on the Big Bend thermal and Ecological Surveys. Contains the Twenty-sixth Quarterly Report by Conservation Consultants, Inc. R. Garrity, ed. 666 p.

Phillips, T. D. 1977c. Ichthyoplankton studies, Chapter 5. In: Tampa Electric Company, Thirthieth Quarterly Report on the Big Bend thermal and Ecological Surveys. Contains the Twenty-seventh Quarterly Report by Conservation Consultants, Inc. R. Garrity, ed. 257 p.

Powell, D., L. M. Dwinell and S. E. Dwinell. 1972. An annotated listing of the fish reference collection at the Florida Department of Natural Resources Marine Research Laboratory. Fla. Dept. Nat. Resour. Mar. Res. Lab., Spec. Sci. Rep. No. 36. 179 p.

Reid, G. K. 1954. An ecological study of the Gulf of Mexico fishes in the vicinity of Cedar Key, Florida. Bull. Mar. Sci. Gulf Carib. 4(1):1-94.

Ross, B. E. 1973. The hydrology and flushing of the bays, estuaries, and nearshore areas of the eastern Gulf of Mexico. In: J. I. Jones, R. E. Ring, M. O. Rinkel and R. E. Smith (eds.). A summary of knowledge of the eastern Gulf of Mexico 1973. Chapter II-D:1-45.

Runyan, S. 1961. Early development of the clingfish, Gobiesox strumosus Cope. Ches. Sci. 2(3-4):113-141.

Scotten, L. N., R. E. Smith, N. S. Smith, K. S. Price and D. P. DeSylva. 1973. Pictorial guide to fish larvae of Delaware Bay, with information and bibliographies useful for the study of fish larvae. Delaware Bay Rep. Ser., Vol. 7, College Marine Studies, Univ. of Delaware. 206 p.

Sette, O. E. and E. H. Ahlstrom. 1948. Estimations of abundance of the eggs of the Pacific pilchard (Sardinops caerulea) off southern California during 1940 and 1941. J. Mar. Res. 7(3):511-542.

Skud, B. E. and W. B. Wilson. 1960. Role of estuarine waters in Gulf fisheries. Trans. 25th North Amer. Wildl. Conf. 1960. p. 320-326.

Springer, V. G. 1961. Notes on and additions to the fish fauna of the Tampa Bay area in Florida. Copeia, 1961 (4):480-482.

Springer, V. G. and K. D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. Fla. State Bd. Conserv. Mar. Res. Lab., Prof. Pap. Ser. No. 1. 104 p.

Stone and Webster. 1970. Progress summary: Environmental Field Studies for Unit No. 1 - Big Bend Station, Tampa Electric Company. 4 p. + Documentation.

Sykes, J. E. and J. H. Finucane. 1966. Occurrence in Tampa Bay, Florida, of immature species dominant in Gulf of Mexico commercial fisheries. NOAA Fish. Bull. 65(2): 369-379.

Tampa Electric Company. 1975a. Ecological surveys of the Big Bend area. Five year data evaluation. July, 1975. 423 p.

Tampa Electric Company. 1975b. Twenty-fourth Quarterly Report on the Big Bend thermal and ecological surveys. Contains Twenty-first Quarterly Report by Conservation Consultants, Inc. R. Garrity, ed. 449 p.

Tranter, D. J. and A. C. Heron. 1967. Experiments on filtration in plankton nets. Aust. J. Mar. Freshwater Res. 18:89-111.

Tranter, D. J. and P. E. Smith. 1968. Filtration performance. In: Zooplankton sampling. Monograph on oceanographic methodologies, No. 2, UNESCO. 174 p.

UNESCO, 1975. Ichthyoplankton. Report of the CICAR ichthyoplankton workshop. UNESCO Tech. Pap. in Mar. Sci. No. 20. 46 p.

Vanucci, M. 1968. Loss of organisms through the meshes. In: Zooplankton sampling. Monograph on oceanographic methodologies No. 2, UNESCO. 174 p.

Voss, G. L., J. S. Bunt, D. P. DeSylva, W. Drost-Hansen, H. Frohlich, W. A. Glooschenko, H. B. Moore, M. J. Provost, C. R. Robins and D. C. Tabb. 1969. Report of the Committee on inshore and estuarine pollution. Rep., Hoover Found. 57 p.

Wiebe, P. H. 1971. A computer model study of zooplankton patchiness and its effects on sampling error. Limnol. & Oceanogr. 16(1):29-38.

Wiebe, P. H. and W. R. Holland. 1968. Plankton patchiness: effects on repeated net tows. Limnol. & Oceanogr. 13(2): 315-321.

APPENDIX 5.A

References useful for identifying Tampa Bay Ichthyoplankton

REFERENCES USEFUL FOR IDENTIFYING TAMPA BAY ICHTHYOPLANKTON

Aboussouan, A. 1968. Oeufs et larves de téléostéen de l'Ouest Africain VI. Larves de Chloroscombrus chrysurus (Linné) et de Blepharis crinitus (Mitchill) (Carangidae). Bull. Inst. Fr. Afr. Noire, Ser. A. 30(3):226-237.

Anderson, W. W. 1957. Early development, spawning, growth, and occurrence of the silver mullet, (Mugil curema) along the South Atlantic coast of the United States. U.S. Fish & Wildlife Serv., Fish. Bull. 57(119): 397-414.

Anderson, W. W. 1958. Larval development, growth, and spawning of striped mullet (Mugil cephalus) along the south Atlantic Coast of the United States. U.S. Fish and Wildlife Serv., Fish. Bull. 58(144):501-509.

Aprieto, V. L. 1974. Early development of five carangid fishes of the Gulf of Mexico and the south Atlantic Coast of the United States. Fish. Bull. 72(2): 415-443.

Bailey, R. M., J. E. Fitch, E. S. Herald, E. A. Lachner, C. C. Lindsey, C. R. Robins, and W. B. Scott. 1970. A list of common and scientific names of fishes from the United States and Canada. Amer. Fish. Soc., Spec. Publ. No. 6:149 pp.

Berrien, P. L. 1974. A description of Atlantic mackeral, Scomber scombrus, eggs and early larvae. U.S. Nat. Mar. Fish Serv., Fish. Bull. 73(1):186-192.

Berry, F. H. 1959. Young jack crevalles (Caranx species) off the southeastern Atlantic coast of the United States. U.S. Fish Wildl. Serv., Fish. Bull. 59(152):417-535.

Breder, C. M., Jr. 1942. On the reproduction of Gobiosoma robustum (Ginsburg). Zoologica 27(11):61-64.

Breder, C. M., Jr. 1922. Some embryonic and larval stages of the winter flounder. Bull. U.S. Bur. Fish. 38:311-315.

Colton, J. B., Jr. and R. R. Marak. 1969. Guide for identifying common planktonic fish eggs and larvae of continental shelf waters, Cape Sable to Block Island. Bureau of Commercial Fisheries, Woods Hole, Massachusetts, Lab. Ref. No. 69-9, Sept. 15, 1969.

Dahl, G. 1964. The metamorphasis from leptocephalus to postlarval stage on the common tarpon Tarpon atlanticus (Cuv. et Val.) Unpubl. Ms., 20 p.

Deufler, E. E. 1958. A comparative study of the postlarvae of three flounders (Paralichthys) in North Carolina. Copeia 1958:112-116.

Dovel, W. L. 1960. Larval development of the oyster toadfish. Opsanus tau. Ches. Sci. 1(3-4):187-195.

Dovel, W. L. 1963. Larval development of clingfish, Gobiesox strumosus 4.0 to 12.0 millimeters total length. Ches. Sci. 4(4):161-166.

Dovel, W. L., J. A. Mihursky and A. J. McErlean. 1969. Life history aspects of the hogchoker, Trinectes maculatus in the Patuxent River Estuary, Maryland. Ches. Sci. 10(2):104-119.

Eldred, B. 1966a. The early development of the spotted worm eel, Myrophis punctatus Lutken (Ophichthidae). Florida Bd. Cons., Mar. Res. Lab., Leaf. Ser. 4 (pt. 1) No. 1, 13 pp.

Eldred, B. 1966b. Larval ladyfish, Elops saurus Linnaeus 1766. (Elopidae) in Florida and adjacent waters. Fla. Bd. Conserv. Mar. Lab., Leaf. Ser. 4(pt. 1) No. 2:1-6.

Eldred, B. 1967a. Larval bonefish, Albula vulpes (Linnaeus, 1758), (Albulidae) in Florida and adjacent waters. Fla. Bd. Cons. Mar. Res. Lab., Leaf. Ser. 4 (pt. 1) No. 3:4 p.

Eldred, B. 1967b. Larval tarpon, Megalops atlanticus Valenciennes, (Megalopidae) in Florida waters. Fla. Bd. Conserv. Mar. Lab., Leaf. Ser. 4(pt. 1) No. 4:1-9.

Eldred, B. 1968. Larvae and glass eels of the American freshwater eel, Anguilla rostrata (Lesueur, 1817) in Florida waters. Florida Bd. Conserv. Mar Res. Lab., Leafl. Ser. 4(pt. 1) No. 8, 4 pp.

Eldred, B. 1972. Note on larval tarpon, Megalops atlanticus (Megalopidae), in the Florida straits. Fla. Dep. Nat. Resour. Mar. Res. Lab., Leafl. Ser. 4(pt. 1) No. 22.

Futch, C. R. 1971. Larvae of Monolene sessilicauda Goode, 1880 (Bothidae). Fla. Dep. Nat. Resour. Mar. Res. Lab., Leaf. Ser 4 (pt.1) No. 21:1-14 p.

Ginsberg, I. 1934. The distinguishing characters of two common species of Microgobius from the east coast of the United States. Copeia (1):35-39.

Hardy, J. D., Jr. and R. K. Johnson. 1974. Description of halfbeak larvae and juveniles from Chesapeake Bay. Ches. Sci. 15(4):241-246.

Herald, E. S. 1966. Artificial key to Atlantic American pipefishes. Unpublished manuscript 12 p.

Hildebrand, S. F. 1922. Notes on habits and development of eggs and larvae of silversides, Menidia menidia and Menidia beryllina. Bull. U. S. Bur. Fish. 38:113-120.

Hildebrand, S. F. 1963a. Family Clupeidae. In Fishes of the Western North Atlantic, Sears Foundation for Marine Research, Mem. 1(3):257-385, 397-442, 452-454.

Hildebrand, S. F. 1963b. Family Engraulidae. In Fishes of the Western North Atlantic, Sears Foundation for Marine Research, Mem. 1(3):152-249.

Hildebrand, S. F. and L. E. Cable. 1930. Development and life history of fourteen teteostean fishes at Beaufort, N. C. U.S. Bur. Fish., Bull. 46:383-488.

Hildebrand, S. F. and L. E. Cable. 1934. Reproduction and development of whiting or kingfishes, drums, spot, croaker, and weakfishes or sea trouts, Family Sciaenidae, of the Atlantic Coast of the United States. U.S. Bur. Fish., Bull. 48(16):48-117.

Hildebrand, S. F. and L. E. Cable. 1938. Further notes on the development and life history of some teleosts at Beaufort, N.C. U.S. Bur. Fish., Bull. 48(24): 505-642.

Hildebrand, S. F. and W. C. Schroeder. 1928. Fishes of Chesapeake Bay. Bull. U.S. Bur. Fish. 43 (pt. 1): 366 pp.

Hoese, H. D. 1965. Spawning of marine fishes in the Port Aransas, Texas area as determined by the distribution of young and larvae. Unpubl. Ph.D. dissertation, University of Texas, Austin, Texas. 140 p.

Houde, E. D., C. R. Futch, and R. Detwyler. 1970. Development of the lined sole, Achirus lineatus, described from laboratory-reared and Tampa Bay specimens. Fla. Dept. Nat. Resour. Mar. Res. Lab., Tech. Ser. No. 62:43 p.

Houde, E. D. and P. L. Fore. 1973. Guide to identity of eggs and larvae of some Gulf of Mexico clupeid fishes. Fla. Dept. Nat. Resour. Mar. Res. Lab., Leafl. Ser. 4 (pt. 1) No. 23, 14 p.

Houde, E. D. and T. Potthoff. 1976. Egg and larval development of the sea bream Archosargus rhomboidalis (Linneaus): Pisces, Sparidae. Bull. Mar. Sci. 26(4):506-529.

Houde, E. D., W. J. Richards, and V. P. Saksena. 1974. Description of the eggs and larvae of scaled sardine Harengula jaguana. Fish. Bull., 72(4):1106-1122.

Houde, E. D. and L. J. Swanson. 1975. Description of eggs and larvae of yellowfin menhaden, Brevoortia smithi. Fish. Bull. 73(3):660-673.

Hubbs, C. L. 1939. The characters and distribution of the Atlantic coast fishes referred to the genus Hypsoblennius. Pap. Mich. Acad. Sci. 24(2):153-157.

Irwin, R. J. 1970. Geographical variation, systematics, and general biology of shore fishes of the genus Menticirrhus, family Sciaenidae. Unpubl. Ph.D. dissertation, Tulane Univ., New Orleans, La. 335 p.

Jaanke, T. E. 1971. Abundance of young sciaenid fishes in Everglades National Park, Florida, in relation to season and other variables. Unpubl. M.S. Thesis, Univ. of Miami, Miami, FL 128 p.

Joseph, E. B., W. H. Massmann, and J. J. Norcross. 1964. The pelagic eggs and early larval stages of the black drum from Chesapeake Bay. Copeia 1964 (2):425-434.

Kuntz, A. 1914. The embryology and larval development of Bairdiella chrysura and Anchovia mitchilli. Bull. U.S. Bur. Fish. 33:1-26.

Kuntz, A. 1916. Notes on the embryology and larval development of five species of teleostean fishes. U.S. Bur. Fish., Bull. 34(1914):409-429.

Kuntz, A. and L. Radcliffe. 1917. Notes on the embryology and larval development of twelve teleostean fishes. U.S. Bur. Fish., Bull. (1915-1916) 35:87-134.

Lippson, A. J. and R. L. Moran. 1974. Manual for identification of early developmental stages of fishes of the Potomac River estuary. Power Plant Siting Program. Md. Dept. Natur. Res. 282 p.

Mansueti, A. J. and J. D. Hardy, Jr. 1967. Development of fishes of the Chesapeake Bay region; an atlas of egg, larval, and juvenile stages. Natural Resources Institute, University Maryland, 202 pp.

Martin, R. A. and J. H. Finucane. 1968. Reproduction and ecology of the longnose killifish. Quart. J. Fla. Acad. Sci. 31(2):101-111.

Miller, G. L. and S. C. Jorgensen. 1973. Meristic characters of some marine fishes of the western Atlantic Ocean. U.S. Dept. of Commerce, Fish. Bull. 71(1):301-317.

Mook, D. 1977. Larval and osteological development of the sheepshead, Archosargus probatocephalus (Pisces: Sparidae) Copeia 1977(1):126-133.

Norcross, J. J., S. L. Richardson, W. H. Massmann, and E. B. Joseph. 1974. Development of young bluefish (Pomatomus saltatrix) and distribution of eggs and young in Virginian coastal waters. Trans. Amer. Fish. Soc. 103(3):477-497.

Olney, J. E. and G. C. Grant. 1976. Early planktonic larvae of the blackcheek tonguefish, Symphurus plagiusa (Pisces:Cynoglossidae), in the lower Chesapeake Bay. Ches. Sci. 17(4):229-237.

Palko, B. J. and W. J. Richards. 1969. The rearing of cowfish and related species from eggs. Salt Water Aquar. Mag., May-June 1969, 4 p.

Pearson, J. C. 1929. Natural history and conservation of the redfish and other commercial sciaenids on the Texas coast. Bull. U.S. Bur. Fish. 44:129-214.

Pearson, J. C. 1941. The young of some marine fishes taken in lower Chesapeake Bay, Virginia, with special reference to the gray seatrout, Cynoscion regalis (Block). U.S. Fish Wildl. Serv., Fish. Bull. 50:79-102.

Potthoff, T. and W. J. Richards. 1970. Juvenile bluefin tuna, Thunnus thynnus (Linnaeus), and other scombrids taken by terns in the Dry Tortugas, Florida. Bull. Mar. Sci. 20(2):389-413.

Richards, W. J., R. V. Miller, and E. D. Houde. 1974. Egg and larval development of the Atlantic thread herring, Opisthonema oglinum. Fish. Bull. 72(4):1123-1136.

Richards, W. J. and B. J. Palko. 1969. Methods used to rear the thread herring, Opisthonema oglinum, from fertilized eggs. Trans. Amer. Fish. Soc., 98(3): 527-529.

Richardson, S. L. and E. B. Joseph. 1973. Larvae and young of western North Atlantic bothid flatfishes Etropus microstomus and Citharichthys arctifrons in the Chesapeake bight. Fish. Bull., 71(3):735-767 pp.

Saksena, V. P. and W. J. Richards. 1975. Description of eggs and larvae of laboratory reared white grunt, Haemulon plumieri (Lacepede) (Pisces, Pomadasyidae). Bull. Mar. Sci. 25(4):523-536.

Scotten, L. N., R. E. Smith, N. S. Smith, K. S. Price, and D. P. de Sylva. 1973. Pictorial guide to fish larvae of Delaware bay, with information and bibliographies useful for the study of fish larvae. Delaware Bay Rep. Ser., Vol. 7, College Marine Studies. Univ. of Delaware. 206 p.

Smith, W. G. and M. P. Fahay. 1970. Descriptions of eggs and larvae of the summer flounder, Paralichthys dentatus. U. S. Fish. Wildl. Serv., Res. Rep. 75. 21 p.

Springer, V. G. and A. J. McErlean. 1961. Spawning seasons and growth of the code goby, Gobiosoma robustum (Pisces: Gobiidae), in the Tampa Bay area. Tulane Stud. in Zool., 9(2):87-98 p.

Springer, V. G. and K. D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. Fla. State Bd. Conserv. Mar. Res. Lab., Prof. Pap. Ser. No. 1, 104 p.

Subrahmanyam, C. B. 1964. Eggs and early development of a carangid from Madras. J. Mar. Biol. Assoc. India 6(1):142-146.

Subrahmanyam, C. B. 1966. Eggs and early development of two more carangids from Madras. J. Mar. Biol. Assoc. India 8(1):188-192.

Welsh, W. W. and C. M. Breder, Jr. 1922. A contribution to the life history of the puffer, Sphaeroides maculatus (Schneider). New York Zool. Soc., Zoologica 2(12): 261-276.

Welsh, W. W. and C. M. Breder, Jr. 1923. Contributions to life histories of Sciaenidae of the eastern United States coast. Bull. U.S. Bur. Fish. 39:141-201.

Wollam, M. B. 1970. Description and distribution of larvae and early juveniles of king mackerel, Scomberomorus cavalla (Cuvier), and Spanish mackerel, Scomberomorus maculatus (Mitchilli); (Pisces: Scombridae); in the western North Atlantic. Fla. Dep. Nat. Resour. Mar. Res. Lab., Tech. Ser. No. 61:35 pp.

APPENDIX 5.B

Seasonal Occurrence of Tampa Bay Fish Larvae

Appendix 5B. Seasonal occurrence of Tampa Bay fish larvae.

Ophichthyidae-snake eels
  Myrophis punctatus-speckled eel worm

Clupeidae-herrings
  Harengula jaguana-scaled sardine
  Brevoortia sp.

Engraulidae-anchovies
  Anchoa mitchilli-bay anchovy

Gobiesocidae-clingfishes
  Gobiesox strumosus-skilletfish

Atherinidae-silversides

Syngnathidae-pipefishes

Carangidae-jacks-pompanos
  Chloroscombrus chrysurus-Atlantic bumper
  Oligoplites saurus-leatherjackets

Pomadasyidae-grunts
  Orthopristis chrysoptera-pigfish

Sparidae-porgies
  Archosargus probatocephalus-sheepshead
  Lagodon rhomboides-pinfish

Sciaenidae-drums
  Bairdiella chrysura-silver perch
  Cynoscion arenarius-sand seatrout
  Cynoscion nebulosus-spotted seatrout
  Leiostomus xanthurus-spot
  Menticirrhus saxatilis-northern kingfish
  Pogonias cromis-black drum

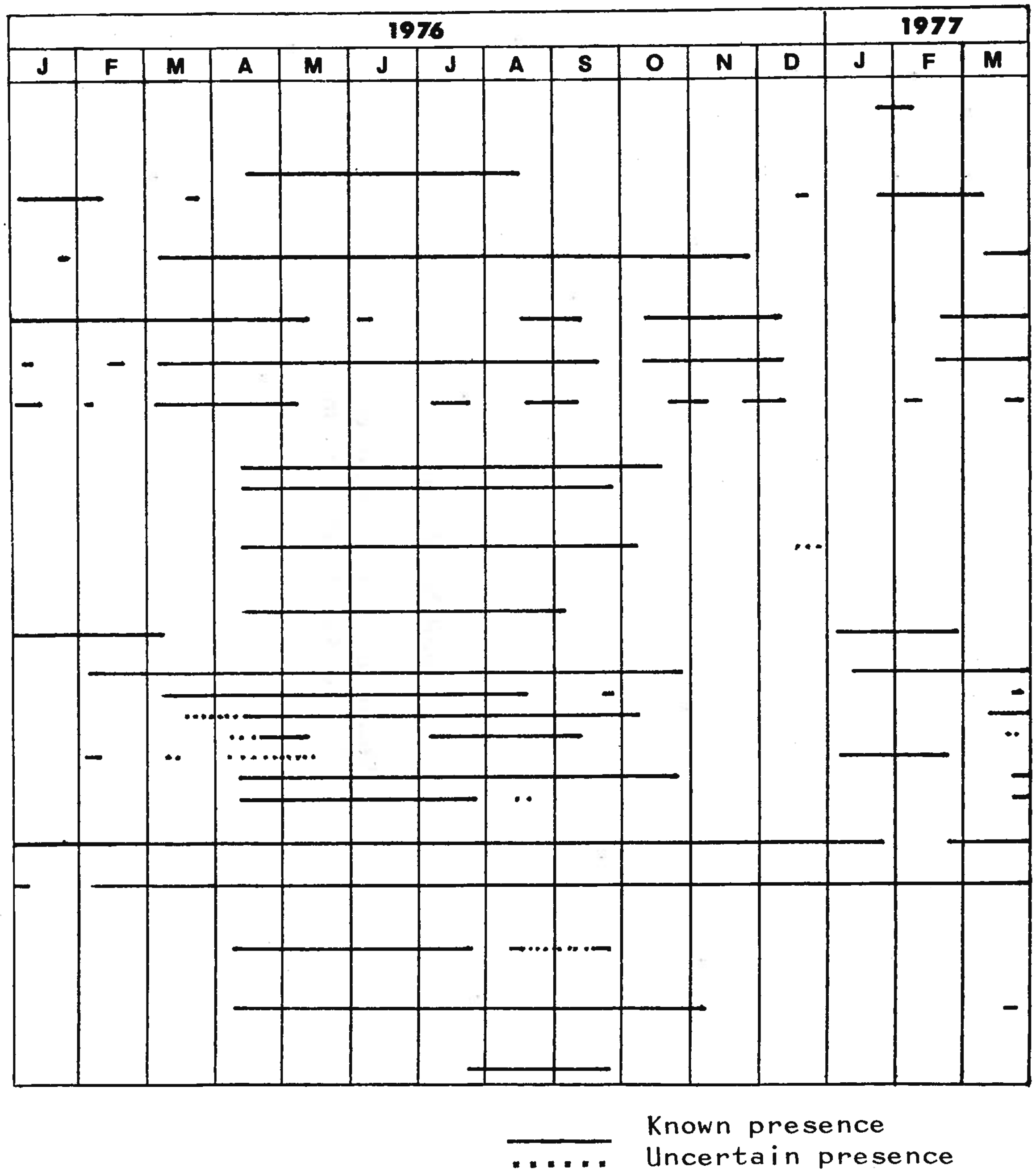
Blenniidae-combtooth blennies

Gobiidae-gobies

Triglidae-searobins
  Prionotus sp.

Soleidae-soles
  Achirus lineatus-lined sole

Cynoglossidae-tonguefish
  Symphurus plagiusa-blackcheek tonguefish



APPENDIX 5.C

Estimated Entrainment of Eggs and Larvae by the Big Bend Plant and by the Dilution Pump

Appendix 5C-1. Estimated Number of Larvae Entrained During January, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Brevoortia patronus	0	7.434×10^4	7.434×10^4
Gobiesocidae			
Gobiesox strumosus	5.254×10^5	0	5.254×10^5
Atherinidae			
Menidia beryllina	0	2.230×10^5	2.230×10^5
Syngnathidae			
Hippocampus erectus	0	3.717×10^4	3.717×10^4
Syngnathus floridae	4.358×10^5	0	4.358×10^5
Sparidae			
Lagodon rhomboides	0	3.717×10^4	3.717×10^4
Blenniidae			
Hypsoblennius hentzi	1.256×10^6	7.434×10^4	1.330×10^6
Gobiidae			
Microgobius gulosus	0	1.487×10^5	1.487×10^5
TOTAL	2.217×10^6	5.940×10^5	2.811×10^6

Appendix 5C-2. Estimated Number of Eggs Entrained During January, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
TOTAL	0	0	0

Appendix 5C-3. Estimated Number of Larvae Entrained During February, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Gobiesocidae			
Gobiesox strumosus	4.340×10^5	0	4.340×10^5
Syngnathidae			
Syngnathus floridae	2.988×10^3	0	2.988×10^3
Syngnathus louisianae	5.816×10^4	0	5.816×10^4
Blenniidae			
Hypsoblennius hentzi	1.626×10^6	0	1.626×10^6
Gobiidae			
Gobiosoma robustum	9.012×10^5	0	9.012×10^5
TOTAL	3.022×10^6	0	3.022×10^6

Appendix 5C-4. Estimated Number of Eggs Entrained During February, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa hepsetus	5.816×10^4	0	5.816×10^4
Anchoa mitchilli	2.582×10^7	0	2.582×10^7
Sciaenidae			
Unidentified	4.471×10^6	0	4.471×10^6
Gobiidae			
Gobiosoma robustum	8.724×10^4	0	8.724×10^4
Soleidae			
Achirus lineatus	2.908×10^4	0	2.908×10^4
Unidentified	2.282×10^5	0	2.282×10^5
TOTAL	3.069×10^7	0	3.069×10^7

Appendix 5C-5. Estimated Number of Larvae Entrained During March, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Brevoortia sp.	8.353×10^5	0	8.353×10^5
Engraulidae			
Anchoa hepsetus	0	5.275×10^6	5.275×10^6
Anchoa mitchilli	1.949×10^6	1.659×10^9	1.661×10^9
Gobiesocidae			
Gobiesox strumosus	2.123×10^6	1.358×10^6	3.481×10^6
Atherinidae			
Menidia beryllina	8.353×10^5	1.478×10^7	1.562×10^7
Syngnathidae			
Hippocampus erectus	2.784×10^5	0	2.784×10^5
Syngnathus louisianae	1.292×10^5	0	1.292×10^5
Carangidae			
Oligoplites saurus	0	1.119×10^6	1.119×10^6
Pomadasyidae			
Orthopristis chrysoptera	0	4.171×10^7	4.161×10^7
Sparidae			
Archosargus probatocephalus	0	1.518×10^7	1.518×10^7
Sciaenidae			
Bairdiella chrysura	2.784×10^5	7.015×10^7	7.043×10^7
Cynoscion arenarius	0	9.427×10^6	9.427×10^6
Menticirrhus saxatilis	0	1.518×10^6	1.581×10^6
Blenniidae			
Chasmodes sp.?	0	3.916×10^6	3.916×10^6
Hypsoblennius hentzi	1.408×10^7	1.302×10^7	2.710×10^7

Appendix 5C-5. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Gobiidae			
Gobiosoma robustum	3.263×10^7	2.333×10^7	5.596×10^7
Gobiosoma sp.?	0	3.116×10^6	3.116×10^6
Microgobius gulosus	2.784×10^5	3.995×10^4	3.184×10^5
Microgobius sp.?	0	5.275×10^6	5.275×10^6
Triglidae			
Prionotus sp.	0	1.358×10^6	1.358×10^6
Soleidae			
Achirus lineatus	0	2.477×10^6	2.477×10^6
Unidentified	0	8.787×10^5	8.787×10^5
TOTAL	5.342×10^7	1.873×10^9	1.926×10^9

Appendix 5C-6. Estimated Number of Eggs Entrained During March, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa hepsetus	1.292×10^5	5.433×10^6	5.562×10^6
Anchoa mitchilli	2.398×10^8	3.757×10^9	3.997×10^9
Unidentified	0	5.595×10^5	5.595×10^5
Cyprinodontidae			
Unidentified	0	5.674×10^6	5.674×10^6
Carangidae			
Oligoplites saurus	0	9.988×10^6	9.988×10^6
Unidentified sp. A	0	8.629×10^6	8.629×10^6
Pomadasyidae			
Orthopristis chrysoptera	0	6.393×10^5	6.393×10^5
Sciaenidae			
Bairdiella chrysura	0	1.157×10^{10}	1.157×10^{10}
Cynoscion sp.	2.227×10^7	7.090×10^8	7.313×10^8
Menticirrhus sp.	2.784×10^5	1.039×10^6	1.317×10^6
Unidentified	8.076×10^6	2.103×10^9	2.111×10^9
Gobiidae			
Gobiosoma robustum	2.811×10^5	0	2.811×10^5
Triglidae			
Prionotus sp.	0	1.758×10^6	1.758×10^6
Soleidae			
Achirus lineatus	6.461×10^4	1.758×10^6	1.822×10^6
TOTAL	2.709×10^8	1.817×10^{10}	1.845×10^{10}

Appendix 5C-7. Estimated Number of Larvae Entrained During April, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	3.948×10^6	1.945×10^5	4.142×10^6
Unidentified	0	4.322×10^4	4.322×10^4
Engraulidae			
Anchoa hepsetus	0	9.395×10^6	9.395×10^6
Anchoa mitchilli	4.614×10^9	3.044×10^9	7.658×10^9
Gobiesocidae			
Gobiesox strumosus	4.137×10^6	2.420×10^6	6.557×10^6
Atherinidae			
Menidia beryllina	3.397×10^6	2.652×10^7	2.991×10^7
Carangidae			
Chloroscombrus chrysurus	1.610×10^7	2.427×10^6	1.853×10^7
Oligoplites saurus	6.117×10^6	2.425×10^6	8.542×10^6
Pomadasyidae			
Orthopristis chrysoptera	2.918×10^7	7.844×10^7	1.076×10^8
Sparidae			
Archosargus probatocephalus	1.106×10^8	3.984×10^7	1.504×10^8
Sciaenidae			
Bairdiella chrysura	1.155×10^8	1.275×10^8	2.430×10^8
Cynoscion arenarius	5.107×10^7	1.896×10^7	7.003×10^7
Cynoscion nebulosus	1.046×10^6	2.233×10^5	1.269×10^6
Menticirrhus americanus	2.323×10^5	0	2.323×10^5
Menticirrhus saxatilis	8.366×10^6	4.209×10^6	1.258×10^7
Pogonias chromis	7.510×10^6	6.481×10^4	7.575×10^6
Unidentified	0	2.039×10^6	2.039×10^6

Appendix 5C-7. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Blenniidae			
Chasmodes sp.?	0	7.039×10^6	7.039×10^6
Hypsoblennius hentzi	1.007×10^7	2.410×10^7	3.417×10^7
Gobiidae			
Gobiosoma robustum	1.687×10^8	4.250×10^7	2.112×10^8
Gobiosoma sp.?	1.046×10^6	5.550×10^6	6.596×10^6
Microgobius gulosus	3.484×10^6	7.115×10^4	3.555×10^6
Microgobius sp.?	1.804×10^7	9.828×10^6	2.787×10^7
Triglidae			
Prionotus sp.	6.155×10^6	2.938×10^6	9.093×10^6
Soleidae			
Achirus lineatus	8.324×10^6	4.563×10^6	1.289×10^7
Trinectes maculatus	0	1.657×10^5	1.657×10^5
Tetraodontidae			
Sphoeroides sp.?	1.046×10^6	0	1.046×10^6
Unidentified	4.623×10^7	2.293×10^6	4.852×10^7
TOTAL	5.234×10^9	3.458×10^9	8.692×10^9

Appendix 5C-8. Estimated Number of Eggs Entrained During April, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	1.719×10^7	3.983×10^6	2.117×10^7
Unidentified	0	7.924×10^4	7.924×10^4
Engraulidae			
Anchoa hepsetus	4.437×10^6	9.850×10^6	1.429×10^7
Anchoa mitchilli	9.579×10^9	7.245×10^9	1.682×10^{10}
Unidentified	0	2.812×10^7	2.812×10^7
Belonidae			
Strongylura notata	0	6.481×10^4	6.481×10^4
Cyprinodontidae			
Unidentified	1.394×10^6	1.011×10^7	1.150×10^7
Carangidae			
Oligoplites saurus	7.410×10^7	1.779×10^7	9.189×10^7
Unidentified sp. A	7.510×10^6	1.908×10^7	2.659×10^7
Pomadasyidae			
Orthopristis chrysoptera	2.169×10^6	1.139×10^6	3.308×10^6
Sciaenidae			
Bairdiella chrysura	2.852×10^{10}	2.098×10^{10}	4.950×10^{10}
Cynoscion sp.	5.427×10^7	1.269×10^9	1.323×10^9
Menticirrhus sp.	3.171×10^6	2.268×10^6	5.439×10^6
Unidentified	1.666×10^9	4.355×10^9	6.021×10^9
Ephippidae			
Chaetodipterus faber	1.719×10^7	0	1.719×10^7
Triglidae			
Prionotus sp.	5.762×10^6	3.477×10^6	9.239×10^6

Appendix 5C-8. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Soleidae			
Achirus lineatus	8.905×10^{6}	4.521×10^{6}	1.343×10^{7}
Unidentified	2.169×10^{6}	1.225×10^{5}	2.291×10^{6}
TOTAL	3.996×10^{10}	3.395×10^{10}	7.391×10^{10}

Appendix 5C-9. Estimated Number of Larvae Entrained During May, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
<u>Harengula jaguana</u>	3.352×10^{6}	4.019×10^{6}	7.371×10^{6}
Unidentified	0	8.933×10^{5}	8.933×10^{5}
Entraulidae			
<u>Anchoa mitchilli</u>	3.950×10^{9}	1.828×10^{9}	5.778×10^{9}
Gobiesocidae			
<u>Gobiesox strumosus</u>	3.615×10^{6}	0	3.615×10^{6}
Atherinidae			
<u>Menidia beryllina</u>	1.354×10^{7}	3.870×10^{6}	1.741×10^{7}
Carangidae			
<u>Chloroscombrus chrysurus</u>	7.482×10^{7}	5.017×10^{7}	1.250×10^{8}
<u>Oligoplites saurus</u>	7.131×10^{6}	8.933×10^{6}	1.606×10^{7}
Pomadasyidae			
<u>Orthopristis chrysoptera</u>	4.509×10^{7}	8.575×10^{7}	1.308×10^{8}
Sparidae			
<u>Archosargus probatocephalus</u>	1.205×10^{8}	2.645×10^{8}	3.850×10^{8}
Sciaenidae			
<u>Bairdiella chrysura</u>	6.738×10^{7}	5.181×10^{7}	1.192×10^{8}
<u>Cynoscion arenarius</u>	5.753×10^{7}	4.481×10^{7}	1.023×10^{8}
<u>Cynoscion nebulosus</u>	4.705×10^{5}	4.615×10^{6}	5.086×10^{6}
<u>Menticirrhus americanus</u>	1.045×10^{5}	0	1.045×10^{5}
<u>Menticirrhus saxatilis</u>	8.394×10^{6}	3.111×10^{7}	3.950×10^{7}
<u>Pogonias chromis</u>	0	1.339×10^{6}	1.339×10^{6}
Unidentified	0	4.213×10^{7}	4.213×10^{7}

Appendix 5C-9. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Blenniidae			
Chasmodes sp.?	6.298×10^5	1.339×10^6	1.969×10^6
Hypsoblennius hentzi	8.185×10^6	1.861×10^7	2.679×10^7
Gobiidae			
Gobiosoma robustum	8.991×10^7	1.936×10^7	1.093×10^8
Gobiosoma sp.?	4.705×10^5	0	4.705×10^5
Microgobius gulosus	1.568×10^6	0	1.568×10^6
Microgobius sp.?	1.163×10^7	8.933×10^6	2.056×10^7
Triglidae			
Prionotus sp.	5.920×10^6	1.072×10^7	1.664×10^7
Soleidae			
Achirus lineatus	4.974×10^6	3.126×10^6	8.100×10^6
Trinectes maculatus	0	3.424×10^6	3.424×10^6
Tetraodontidae			
Sphoeroides sp.?	4.705×10^5	0	4.705×10^5
Unidentified	0	1.503×10^7	1.503×10^7
TOTAL	4.476×10^9	2.502×10^9	6.949×10^9

Appendix 5C-10. Estimated Number of Eggs Entrained During May, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	5.113×10^{8}	8.232×10^{7}	5.936×10^{8}
Unidentified	0	1.638×10^{6}	1.638×10^{6}
Engraulidae			
Anchoa hepsetus	9.549×10^{6}	3.573×10^{6}	1.312×10^{7}
Anchoa mitchilli	1.350×10^{10}	1.141×10^{10}	2.491×10^{10}
Unidentified	7.244×10^{7}	5.605×10^{8}	6.329×10^{8}
Belonidae			
Strongylura notata	0	1.339×10^{6}	1.339×10^{6}
Cyprinodontidae			
Unidentified	6.272×10^{5}	0	6.272×10^{5}
Carangidae			
Oligoplites saurus	2.801×10^{7}	0	2.801×10^{7}
Unidentified sp. A	1.758×10^{8}	7.667×10^{7}	2.525×10^{8}
Sciaenidae			
Bairdiella chrysura	1.831×10^{10}	7.586×10^{9}	2.590×10^{10}
Cynoscion sp.	3.080×10^{8}	1.193×10^{8}	4.273×10^{8}
Menticirrhus sp.	6.298×10^{6}	8.634×10^{6}	1.493×10^{7}
Unidentified	8.100×10^{6}	1.257×10^{10}	1.258×10^{10}
Triglidae			
Prionotus sp.	1.222×10^{7}	7.145×10^{6}	1.937×10^{7}
Soleidae			
Achirus lineatus	9.330×10^{6}	2.873×10^{7}	3.806×10^{7}
Unidentified	0	2.531×10^{6}	2.531×10^{6}
TOTAL	3.295×10^{10}	3.246×10^{10}	6.541×10^{10}

Appendix 5C-11. Estimated Number of Larvae Entrained During June, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	1.342×10^6	7.575×10^6	8.917×10^6
Unidentified	0	4.322×10^4	4.322×10^4
Engraulidae			
Anchoa hepsetus	0	3.102×10^5	3.102×10^5
Anchoa mitchilli	9.439×10^8	4.089×10^8	1.353×10^9
Gobiesocidae			
Gobiesox strumosus	2.153×10^5	0	2.153×10^5
Atherinidae			
Membras martinica	7.550×10^4	2.286×10^5	3.041×10^5
Menidia beryllina	1.772×10^6	2.701×10^6	4.473×10^6
Syngnathidae			
Syngnathus louisianae	0	2.721×10^4	2.721×10^4
Carangidae			
Chloroscombrus chrysurus	5.345×10^6	6.183×10^6	1.153×10^7
Oligoplites saurus	9.371×10^5	1.809×10^6	2.746×10^6
Pomadasyidae			
Orthopristis chrysoptera	2.716×10^7	5.432×10^7	8.148×10^7
Sparidae			
Archosargus probatocephalus	9.890×10^6	1.751×10^7	2.740×10^7
Sciaenidae			
Bairdiella chrysura	1.115×10^7	1.425×10^7	2.540×10^7
Cynoscion arenarius	1.921×10^7	8.765×10^6	2.798×10^7
Cynoscion nebulosus	0	2.233×10^5	2.233×10^5
Menticirrhus saxatilis	4.534×10^6	1.041×10^7	1.495×10^7
Pogonias chromis	1.811×10^5	1.343×10^6	1.525×10^6
Unidentified	0	2.343×10^6	2.343×10^6

Appendix 5C-11. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Blenniidae			
Chasmodes sp.?	2.646×10^6	6.481×10^4	2.711×10^6
Hypsoblennius hentzi	2.932×10^6	1.847×10^6	4.779×10^6
Gobiidae			
Gobiosoma robustum	1.162×10^8	5.512×10^7	1.713×10^8
Gobiosoma sp.?	2.114×10^5	0	2.114×10^5
Microgobius gulosus	1.359×10^6	2.939×10^5	1.653×10^6
Microgobius sp.?	5.757×10^6	4.841×10^5	6.241×10^6
Triglidae			
Prionotus sp.	3.211×10^6	2.010×10^6	5.221×10^6
Soleidae			
Achirus lineatus	2.131×10^6	2.764×10^5	2.407×10^6
Trinectes maculatus	4.680×10^5	9.276×10^5	1.396×10^6
Unidentified	1.359×10^5	8.526×10^5	9.885×10^5
TOTAL	1.161×10^9	5.926×10^8	1.754×10^9

Appendix 5C-12. Estimated Number of Eggs Entrained During June, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	2.980×10^7	8.958×10^6	3.876×10^7
Unidentified	0	7.924×10^4	7.924×10^4
Engraulidae			
Anchoa hepsetus	4.813×10^5	1.729×10^5	6.542×10^5
Anchoa mitchilli	3.429×10^9	3.168×10^9	6.597×10^9
Unidentified	9.906×10^7	3.462×10^8	4.453×10^8
Ephippidae			
Chaetodipterus faber	0	2.721×10^4	2.721×10^4
Belonidae			
Strongylura notata	0	6.481×10^4	6.481×10^4
Carangidae			
Oligoplites saurus	0	4.354×10^4	4.354×10^4
Unidentified sp. A	1.126×10^7	1.081×10^7	2.207×10^7
Pomadasyidae			
Orthopristis chrysoptera	3.153×10^6	0	3.153×10^6
Sciaenidae			
Bairdiella chrysura	3.425×10^9	3.744×10^9	7.169×10^9
Cynoscion sp.	6.020×10^7	7.256×10^7	1.328×10^8
Menticirrhus sp.	3.314×10^6	5.970×10^6	9.284×10^6
Unidentified	1.570×10^6	7.590×10^8	7.606×10^8
Triglidae			
Prionotus sp.	6.123×10^6	1.064×10^6	7.187×10^6
Soleidae			
Achirus lineatus	2.254×10^7	8.748×10^6	3.129×10^7
Unidentified	0	1.660×10^5	1.660×10^5
TOTAL	7.092×10^9	8.126×10^9	1.522×10^{10}

Appendix 5C-13. Estimated Number of Larvae Entrained During July, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	1.629×10^7	3.524×10^7	5.153×10^7
Engraulidae			
Anchoa hepsetus	0	4.033×10^6	4.033×10^6
Anchoa mitchilli	4.197×10^9	2.901×10^9	7.098×10^9
Gobiesocidae			
Gobiesox strumosus	1.177×10^6	0	1.177×10^6
Atherinidae			
Membras martinica	9.815×10^5	2.971×10^6	3.953×10^6
Syngnathidae			
Syngnathus louisianae	0	3.538×10^5	3.538×10^5
Carangidae			
Chloroscombrus chrysurus	2.842×10^7	3.395×10^7	6.237×10^7
Oligoplites saurus	8.756×10^6	1.003×10^7	1.879×10^7
Pomadasyidae			
Orthopristis chrysoptera	3.202×10^8	2.031×10^8	5.233×10^8
Sparidae			
Archosargus probatocephalus	1.469×10^7	7.968×10^6	2.266×10^7
Sciaenidae			
Bairdiella chrysura	4.318×10^7	2.993×10^7	7.311×10^7
Cynoscion arenarius	1.509×10^7	7.025×10^7	8.534×10^7
Cynoscion nebulosus	3.420×10^5	4.409×10^5	7.829×10^5
Menticirrhus saxatilis	4.736×10^7	4.533×10^7	9.269×10^7
Pogonias chromis	2.355×10^6	2.751×10^6	5.086×10^6
Unidentified	0	5.064×10^6	5.064×10^6

Appendix 5C-13. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Ephippidae			
Chaetodipterus faber	0	3.674×10^5	3.674×10^5
Blenniidae			
Chasmodes sp.?	2.355×10^6	0	2.355×10^6
Hypsoblennius hentzi	4.482×10^6	5.175×10^6	9.657×10^6
Gobiidae			
Gobiosoma robustum	1.499×10^7	3.035×10^7	4.534×10^7
Gobiosoma sp.?	2.748×10^6	0	2.748×10^6
Microgobius gulosus	1.997×10^7	8.841×10^6	2.881×10^7
Microgobius sp.?	5.888×10^6	1.834×10^6	7.722×10^6
Triglidae			
Prionotus sp.	3.336×10^6	7.076×10^5	4.044×10^6
Soleidae			
Achirus lineatus	4.901×10^6	3.635×10^6	8.536×10^6
Trinectes maculatus	6.084×10^6	2.123×10^6	8.207×10^6
Cynoglossidae			
Symphurus plagiusa	0	3.674×10^5	3.674×10^5
Unidentified	3.742×10^6	1.627×10^6	5.369×10^6
TOTAL	4.764×10^9	3.197×10^9	7.961×10^9

Appendix 5C-14. Estimated Number of Eggs Entrained During July, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	4.186×10^7	4.923×10^7	9.109×10^7
Engraulidae			
Anchoa mitchilli	1.673×10^9	3.414×10^9	5.087×10^9
Unidentified	7.458×10^6	1.847×10^7	2.593×10^7
Ephippidae			
Chaetodipterus faber	0	3.538×10^5	3.538×10^5
Carangidae			
Oligoplites saurus	0	5.661×10^5	5.661×10^5
Unidentified sp. A	1.848×10^7	6.957×10^7	9.390×10^7
Pomadasyidae			
Orthopristis chrysoptera	4.907×10^6	0	4.907×10^6
Sciaenidae			
Bairdiella chrysura	2.380×10^9	1.927×10^9	2.165×10^9
Cynoscion sp.	1.126×10^8	1.179×10^8	2.499×10^8
Menticirrhus sp.	8.056×10^7	9.293×10^7	1.735×10^8
Unidentified	1.082×10^8	1.330×10^9	1.439×10^9
Soleidae			
Achirus lineatus	1.523×10^7	8.490×10^6	2.372×10^7
Unidentified	0	5.661×10^5	5.661×10^5
TOTAL	4.442×10^9	7.029×10^9	1.147×10^{10}

Appendix 5C-15. Estimated Number of Larvae Entrained During August, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	5.934×10^9	5.426×10^8	6.477×10^9
Gobiesocidae			
Gobiesox strumosus	3.123×10^5	3.266×10^4	3.450×10^5
Atherinidae			
Membras martinica	0	6.286×10^5	6.286×10^5
Syngnathidae			
Syngnathus louisianae	8.011×10^5	0	8.011×10^5
Carangidae			
Chloroscombrus chrysurus	4.071×10^7	1.841×10^7	5.912×10^7
Oligoplites saurus	5.604×10^6	3.129×10^5	5.917×10^6
Pomadasyidae			
Orthopristis chrysoptera	1.201×10^7	7.102×10^6	1.911×10^7
Sparidae			
Archosargus probatocephalus	1.335×10^6	2.367×10^5	1.572×10^6
Sciaenidae			
Bairdiella chrysura	0	6.286×10^5	6.286×10^5
Cynoscion arenarius	1.545×10^7	6.599×10^6	2.205×10^7
Cynoscion nebulosus	3.468×10^6	2.147×10^6	5.615×10^6
Menticirrhus saxatilis	9.146×10^7	2.164×10^7	1.131×10^8
Pogonias chromis	0	6.286×10^5	6.286×10^5
Unidentified	3.471×10^6	0	3.471×10^6
Cyprinodontidae			
Fundulus grandis	0	2.286×10^5	2.286×10^5

Appendix 5C-15. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Blenniidae			
Chasmodes sp.?	2.670×10^6	4.354×10^4	2.714×10^6
Hypsoblennius hentzi	4.009×10^6	4.109×10^5	4.420×10^6
Gobiidae			
Gobiosoma robustum	9.725×10^6	5.960×10^5	1.032×10^7
Microgobius gulosus	1.243×10^8	2.045×10^7	1.448×10^8
Microgobius sp.?	5.839×10^6	3.535×10^6	9.374×10^6
Unidentified	0	5.443×10^4	5.443×10^4
Triglidae			
Prionotus sp.	3.471×10^6	3.266×10^4	3.504×10^6
Soleidae			
Achirus lineatus	2.598×10^7	2.566×10^6	2.855×10^7
Cynoglossidae			
Symphurus plagiusa	0	5.388×10^5	5.388×10^5
Unidentified	5.872×10^6	3.050×10^6	8.922×10^6
TOTAL	6.290×10^9	6.325×10^8	6.923×10^9

Appendix 5C-16. Estimated Number of Eggs Entrained During August, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	1.613×10^8	1.960×10^8	3.573×10^8
Atherinidae			
Unidentified	0	3.266×10^4	3.266×10^4
Carangidae			
Unidentified sp. A	6.943×10^6	3.510×10^6	1.045×10^7
Sciaenidae			
Cynoscion sp.	2.523×10^7	1.235×10^7	3.758×10^7
Menticirrhus sp.	3.152×10^8	7.799×10^6	3.230×10^8
Unidentified	9.112×10^7	1.400×10^8	2.311×10^8
Triglidae			
Prionotus sp.	0	2.694×10^5	2.694×10^5
Soleidae			
Achirus lineatus	5.380×10^6	0	5.380×10^6
TOTAL	6.052×10^8	3.599×10^8	9.652×10^8

Appendix 5C-17. Estimated Number of Larvae Entrained During September, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	2.902×10^{9}	2.103×10^{8}	3.112×10^{9}
Gobiesocidae			
Gobiesox strumosus	1.874×10^{6}	1.959×10^{5}	2.070×10^{6}
Carangidae			
Chloroscombrus chrysurus	1.394×10^{7}	7.184×10^{6}	2.112×10^{7}
Oligoplites saurus	3.013×10^{6}	2.613×10^{5}	3.274×10^{6}
Pomadasyidae			
Orthopristis chrysoptera	2.601×10^{4}	5.878×10^{5}	6.138×10^{5}
Sparidae			
Archosargus probatocephalus	0	3.919×10^{5}	3.919×10^{5}
Sciaenidae			
Bairdiella chrysura	2.601×10^{4}	0	2.601×10^{4}
Cynoscion arenarius	6.786×10^{6}	2.613×10^{5}	7.047×10^{6}
Cynoscion nebulosus	5.403×10^{6}	0	5.403×10^{6}
Menticirrhus saxatilis	2.872×10^{7}	1.236×10^{7}	4.108×10^{7}
Blenniidae			
Chasmodes sp.?	0	2.613×10^{5}	2.613×10^{5}
Hypsoblennius hentzi	2.140×10^{7}	1.611×10^{6}	2.301×10^{7}
Gobiidae			
Gibiosoma robustum	4.824×10^{7}	2.547×10^{6}	5.079×10^{7}
Microgobius gulosus	3.627×10^{8}	4.580×10^{7}	4.085×10^{8}
Microgobius sp.?	2.455×10^{7}	7.946×10^{6}	3.250×10^{7}
Unidentified	0	3.266×10^{5}	3.266×10^{5}
Triglidae			
Prionotus sp.	0	1.959×10^{5}	1.959×10^{5}

Appendix 5C-17. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Soleidae			
Achirus lineatus	1.502×10^7	2.395×10^6	1.741×10^7
Unidentified	0	1.284×10^6	1.284×10^6
TOTAL	3.434×10^9	2.939×10^8	3.728×10^9

Appendix 5C-18. Estimated Number of Eggs Entrained During September, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	9.298×10^7	3.338×10^7	1.264×10^8
Atherinidae			
Menidia beryllina?	0	1.959×10^5	1.959×10^5
Carangidae			
Unidentified sp. A	0	5.878×10^5	5.878×10^5
Sciaenidae			
Cynoscion sp.	2.676×10^6	1.371×10^6	4.047×10^6
Menticirrhus sp.	1.078×10^7	2.221×10^6	1.300×10^7
Unidentified	1.719×10^8	2.913×10^7	2.010×10^8
Soleidae			
Achirus lineatus	1.926×10^6	0	1.926×10^6
TOTAL	2.803×10^8	6.689×10^7	3.472×10^8

Appendix 5C-19. Estimated Number of Larvae Entrained During October, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	3.689×10^{8}	1.487×10^{7}	3.837×10^{8}
Gobiesocidae			
Gobiesox strumosus	1.935×10^{6}	0	1.935×10^{6}
Pomadasyidae			
Orthopristis chrysoptera	7.023×10^{5}	0	7.023×10^{5}
Sciaenidae			
Cynoscion arenarius	7.023×10^{5}	0	7.023×10^{5}
Menticirrhus saxatilis	5.150×10^{6}	1.792×10^{6}	6.942×10^{6}
Blenniidae			
Chasmodes sp.?	2.544×10^{6}	2.317×10^{5}	2.776×10^{6}
Hypsoblennius hentzi	8.210×10^{6}	3.227×10^{6}	1.144×10^{7}
Gobiidae			
Gobiosoma robustum	2.325×10^{7}	8.113×10^{5}	2.406×10^{7}
Microgobius gulosus	1.989×10^{8}	8.858×10^{6}	2.078×10^{8}
Microgobius sp.?	6.140×10^{6}	1.283×10^{6}	7.423×10^{6}
Soleidae			
Achirus lineatus	7.023×10^{5}	1.025×10^{6}	1.728×10^{6}
Unidentified	1.908×10^{6}	5.619×10^{5}	2.470×10^{6}
TOTAL	6.191×10^{8}	3.266×10^{7}	6.517×10^{8}

Appendix 5C-20. Estimated Number of Eggs Entrained During October, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	2.672×10^7	0	2.672×10^7
Sciaenidae			
Menticirrhus sp.	7.023×10^5	0	7.023×10^5
Unidentified	1.709×10^7	0	1.709×10^7
Soleidae			
Achirus lineatus	1.405×10^6	0	1.405×10^6
TOTAL	4.592×10^7	0	4.592×10^7

Appendix 5C-21. Estimated Number of Larvae Entrained During November, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	8.343×10^5	1.447×10^6	2.281×10^6
Gobiesocidae			
Gobiesox strumosus	1.864×10^6	0	1.864×10^6
Atherinidae			
Membras martinica	9.646×10^5	1.308×10^6	2.272×10^6
Syngnathidae			
Syngnathus floridae	0	1.635×10^5	1.635×10^5
Syngnathus sp.	0	1.635×10^5	1.635×10^5
Blenniidae			
Chasmodes sp.?	0	5.675×10^4	5.675×10^4
Hypsoblennius hentzi	5.475×10^6	8.728×10^5	6.348×10^6
Gobiidae			
Gobiosoma robustum	7.235×10^5	1.987×10^5	9.222×10^5
Microgobius gulosus	3.259×10^6	1.500×10^6	4.759×10^6
Microgobius sp.	0	1.987×10^5	1.987×10^5
Soleidae			
Achirus lineatus	0	1.702×10^5	1.702×10^5
Unidentified	0	5.675×10^4	5.675×10^4
TOTAL	1.312×10^7	6.136×10^6	1.926×10^7

Appendix 5C-22. Estimated Number of Eggs Entrained During November, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Sciaenidae			
Unidentified	9.646×10^5	8.172×10^4	1.046×10^6
TOTAL	9.646×10^5	8.172×10^4	1.046×10^6

Appendix 5C-23. Estimated Number of Larvae Entrained During December, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Brevoortia smithi?	0	2.340×10^5	2.340×10^5
Gobiesocidae			
Gobiesox strumosus	4.491×10^5	2.340×10^5	6.831×10^5
Atherinidae			
Membras martinica	2.994×10^5	5.962×10^5	8.956×10^5
Syngnathidae			
Syngnathus floridae	0	2.646×10^5	2.646×10^5
Syngnathus sp.	0	3.065×10^4	3.065×10^4
Sparidae			
Lagodon rhomboides	0	1.335×10^5	1.335×10^5
Blenniidae			
Hypsoblennius hentzi	5.987×10^5	4.987×10^5	1.097×10^6
Gobiidae			
Gobiosoma robustum	2.245×10^5	0	2.245×10^5
Microgobius gulosus	2.994×10^5	1.532×10^4	3.147×10^5
TOTAL	1.871×10^6	2.007×10^6	3.878×10^6

Appendix 5C-24. Estimated Number of Eggs Entrained During December, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Sciaenidae			
Unidentified	2.994×10^5	1.532×10^4	3.147×10^5
TOTAL	2.994×10^5	1.532×10^4	3.147×10^5

Appendix 5C-25. Estimated Number of Larvae Entrained During January, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Ophichthidae			
Myrophis punctata	0	2.865×10^5	2.865×10^5
Clupeidae			
Brevoortia smithi?	0	3.581×10^4	3.581×10^4
Atherinidae			
Membras martinica	0	1.432×10^5	1.432×10^5
Sparidae			
Lagodon rhomboides	0	2.436×10^6	2.436×10^6
Sciaenidae			
Leiostomus xanthurus	2.437×10^6	3.581×10^4	2.473×10^6
TOTAL	2.437×10^6	2.937×10^6	5.374×10^6

Appendix 5C-26. Estimated Number of Eggs Entrained During January, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Sciaenidae			
Cynoscion sp.	0	3.581×10^4	3.581×10^4
TOTAL	0	3.581×10^4	3.581×10^4

Appendix 5C-27. Estimated Number of Larvae Entrained During February, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Ophichthidae			
Myrophis punctatus	4.683×10^6	4.824×10^5	5.165×10^6
Clupeidae			
Brevoortia smithi	0	6.030×10^4	6.030×10^4
Gobiesocidae			
Gobiesox strumosus	0	1.306×10^5	1.306×10^5
Atherinicae			
Membras martinica	0	2.413×10^5	2.413×10^5
Sparidae			
Lagodon rhomboides	5.854×10^5	3.136×10^6	3.720×10^6
Sciaenidae			
Leiostomus xanthurus	1.171×10^6	1.909×10^5	1.362×10^6
Blenniidae			
Hypsoblennius hentzi	4.747×10^5	3.919×10^5	8.666×10^5
Gobiidae			
Gobiosoma robustum	0	1.959×10^5	1.959×10^5
TOTAL	6.914×10^6	4.829×10^6	1.174×10^7

Appendix 5C-28. Estimated Number of Eggs Entrained During February, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	0	1.306×10^5	1.306×10^5
Sciaenidae			
Cynoscion	1.648×10^6	3.979×10^6	5.627×10^6
TOTAL	1.648×10^6	4.110×10^6	5.758×10^6

Appendix 5C-29. Estimated Number of Larvae Entrained During March, 1977

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	1.036×10^9	2.578×10^8	1.294×10^9
Gobiesocidae			
Gobiesox strumosus	3.006×10^6	2.556×10^6	5.562×10^6
Atherinidae			
Membras martinica	6.803×10^6	6.748×10^5	7.478×10^6
Sciaenidae			
Bairdiella chrysura	0	5.143×10^5	5.143×10^5
Cynoscion arenarius	0	1.870×10^6	1.870×10^6
Cynoscion nebulosus	0	4.408×10^5	4.408×10^5
Leiostomus xanthurus	0	1.306×10^5	1.306×10^5
Menticirrhus saxatilis	0	2.204×10^5	2.204×10^5
Pogonias chromis	5.592×10^6	7.818×10^5	6.374×10^6
Unidentified	1.919×10^6	5.878×10^5	2.507×10^6
Blenniidae			
Hypsoblennius hentzi	7.988×10^6	4.333×10^6	1.232×10^7
Gobiidae			
Gobiosoma robustum	1.362×10^7	1.238×10^6	1.486×10^7
Microgobius gulosus	1.221×10^7	3.894×10^6	2.693×10^7
Microgobius sp.?	0	5.143×10^5	5.143×10^5
TOTAL	1.087×10^9	2.756×10^8	3.843×10^8

Appendix 5C-30. Estimated Number of Eggs Entrained During March, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Brevoortia smithi	5.385×10^5	1.159×10^6	1.697×10^6
Engraulidae			
Anchoa hepsetus	3.590×10^5	1.605×10^5	2.056×10^6
Anchoa mitchilli	1.362×10^{10}	6.885×10^9	2.050×10^{10}
Sciaenidae			
Cynoscion sp.	8.028×10^6	7.728×10^6	1.576×10^7
Unidentified	4.784×10^7	3.083×10^7	7.867×10^7
Triglidae			
Prionotus sp.	0	1.070×10^5	1.070×10^5
TOTAL	1.368×10^{10}	6.925×10^9	2.060×10^{10}

CHAPTER FIVE

PART II

MORTALITY TO FISH EGGS EXPERIENCING PASSAGE THROUGH THE COOLING SYSTEM OF THE BIG BEND POWER PLANT AS DETERMINED BY REARING EXPERIMENTS

BY

JOHN M. DAILY
T. DUANE PHILLIPS
J. MICHAEL LYONS

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LIST OF PARTICIPANTS

Principal Investigator:	T. Duane Phillips B.A. Staff Biologist
Research Assistants:	John M. Daily B.A. Staff Biologist
	J. Michael Lyons, B.A. Staff Biologist
	Allen G. Shuey, B.S. Staff Biologist
	Kimberly Mason Marine Science Technician

INTRODUCTION

General

Planktonic organisms, including fish eggs and larvae, are subject to mechanical, thermal, and chemical damage while passing through condensor tubes of power plants using once-through cooling systems. The laboratory rearing portion of this study was established to attempt to determine the mortality of fish eggs due to their entrainment through the Big Bend power plant. This mortality can be estimated by comparing the hatching and survival rates of eggs collected at the discharge.

Literature Review

The past thirty years have seen an increase of interest in culturing marine fish larvae. The published results of experiments conducted during this time offer successful techniques for rearing the larvae of some fish species reported in the Big Bend area, including: the yellowfin menhaden, Brevoortia smithi (Houde and Swanson, 1975); the scaled sardine, Harengula jaguana (Houde and Palko, 1970; Saksena, Steinmetz and Houde, 1972; Houde, Richards, and Saksena, 1974); the Atlantic thread herring, Opisthonema oglinum (Richards and Palko, 1969); the bay anchovy, Anchoa mitchilli (Detwyler and Houde, 1970; Saksena and Houde, 1972); the striped mullet, Mugil cephalus (Nash, Kuo, and McConnel, 1974); the white mullet, Mugil curema (Houde, Berkeley, Klinovsky, and Schekter, 1976); and the lined sole, Achirus lineatus (Houde, Futch, and Detwyler, 1970).

Other workers have cultured additional species not found in the Big Bend area (Blaxter, 1962; Jones, 1972; Houde, 1972; Rao, 1974; Houde, 1975; Stepian, 1976; Middaugh and Lempesis, 1976; May, 1976).

May (1971) assembled an annotated bibliography of papers on attempts to rear marine fish larvae, and Shelbourne (1965) and Houde (1973) have both reviewed the subject. Houde and Taniguchi (1977) outlined the procedures used to culture larvae of marine fishes at the Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida.

The detrimental effects of thermal shock on fish eggs and larvae were revealed in laboratory studies conducted by

Hoss, Hettler, and Coston (1974), Schubel and Auld (1974), Schubel (1974), and Frank (1974).

Limitations

The rearing methods we used in our experiments were identical to the procedures suggested by Houde and Taniguchi (1977). Since the physiological requirements of developing larvae are virtually unknown, the effects of the rearing techniques themselves on the survival of the larvae are also unknown. Certainly mechanical damage inflicted on the eggs by collecting and sorting is an inherent problem in any rearing experiment.

The hatching percentages obtained during the experiments may also have been influenced by the developmental stage of the eggs at the time of their collection. Frank (1974) reported that eggs of carp (*Cyprinnus carpio* L.) were more susceptible to thermal damage during the cleavage and blastopore closing stages than at any other time. Schubel (1974) observed lower hatching percentages of blueback herring, *Alosa aestivalis*, and alewife, *Alosa pseudoharengus*, eggs during the blastopore closing stage of development than during other developmental stages, although he found that these differences were not statistically significant.

Because of technical problems involving aeration and the limitations listed above, we were prevented from observing any long term survival rates. However, we do not feel that we were deterred from fulfilling the objectives of this study.

METHODS

Experiments were conducted whenever eggs were sufficiently abundant. Eggs were collected with a one-meter diameter, 363 μm mesh plankton net from both the intake and discharge of the plant and were returned to the laboratory to be sorted. Using pipettes, one hundred or one hundred fifty eggs of an abundant species (usually Anchoa mitchilli) were simultaneously removed from the raw samples obtained from the plant intake and discharge. The eggs were initially placed into 600 ml Pyrex beakers containing water from the experimental aquaria, before being stocked into ten gallon aquaria. The interval between the time of the collection of the eggs and their introduction to the experimental aquaria (usually an hour) provided time for the eggs (especially those collected from the plant discharge) to acclimate to room temperature. This acclimation period reduced the possibility of the eggs incurring a temperature shock, resulting from the large temperature differences which were often present between the collecting point and the experimental aquaria. Water for the aquaria was obtained from the discharge canal and filtered through a 35um mesh Nitex nylon cloth and a Vortex diatom filter. Eggs from the intake and discharge were placed into separate ten gallon aquaria. The aquaria were equipped with heaters and aerators and were provided with continuous fluorescent illumination. The rationale for providing a continuous light source was that some larvae become inactive at low light intensities and sink to the tank bottom. Here they could come into contact with toxic sediments and other detritus which could elicit harmful effects (Houde, 1973). Air was supplied by direct lines from the power plant. Wooden air "stones" were adjusted to provide a low air flow to protect the larvae from abrasion caused by turbulence. The heaters were used to maintain the temperature ($\pm$ 1.5°C) in the tanks at a level corresponding to that of the water from the plant intake. (This procedure was later modified to reflect findings by Rebel (1973). He observed the highest survival rates for laboratory reared *Anchoa mitchilli* larvae at experimental temperatures of 25.6° - 31.0°C. Beginning with our eighth experiment, when the water temperature in the intake canal was 24°C, the temperatures in all the aquaria were maintained at 29° - 31°C. At these temperatures we hoped to obtain the highest possible longevity and survival rates.)

Each rearing tank contained an algal bloom of either *Nannochloris occulata* or *Isochrysis galbana*. It has been suggested (Houde, 1973) that an algal bloom removes from the culture medium toxic metabolic products of both the growing larvae and their food organisms.

The larvae were fed zooplankton, collected with a $\frac{1}{2}$-meter diameter, 35 µm mesh plankton net. Using different mesh sizes of Nitex nylon cloth, the zooplankton was separated into three size fractions: that greater than 300 microns; that between 110-300 microns; and that between 53-110 microns. Organisms of the smallest size fraction were fed to the larvae on the first day of eye pigmentation. The food size was increased proportionately with the growth of the larvae.

RESULTS

A total of eleven rearing experiments, utilizing eggs from both the plant intake (station I-6) and discharge (station I-1) were conducted during the study period. The majority (98.8%) of the 3,118 eggs cultured were those of the bay anchovy, *Anchoa mitchilli*. Eggs of the lined sole, *Achirus lineatus*, the silver perch, *Bairdiella chrysura* and an unidentified species, comprised .16%, .38%, and .66% respectively, of the total and were reared only in the first of these experiments. No anchovies hatched in the first experiment utilizing eggs from the plant intake and discharge. The identity of the larvae that did hatch was not discernable.

No larvae survived longer than a week in any of the experiments.

The results of the rearing experiments utilizing eggs from both the intake and discharge are summarized in Table 5.19.

Table 5.18. Results of experiments utilizing eggs collected from the plant intake and discharge.

Eggs collected at the plant intake (1-6)-'control'					Eggs collected at the plant discharge		
Date	Exp. No.	% Hatching	Surf. temp. °C	Aquaria temp °C	% Hatching	Surf temp. °C	Aquaria temp °C
7/27/76	1	4	30.5	29-30.5	3	39	29-30
8/9/76	2	35	31.5	31.5-32.5	0	39	30.5-31.5
8/24/76	3	47	30	28-30	7	38	29-30
	4	47	30	30	7	38	29-30
9/14/76	5	60	30	29.5-31	34	38	29-30
	6	60	30	30	32	38	29-30
	*7	40	30	23-24	37.5	38	22-23
3/29/77	8	87.5	24	29-30	45.6	29	30-31
	9	78.8	24	30-31	46.3	29	30-31
5/19/77	10	26.7	25	30	22.7	29	30
	11	25.3	25	30	14.7	29	30
$\overline{X}$		46.5			26.9		

* no water heaters were available for this experiment.

DISCUSSION

The hatching percentages of eggs collected from the plant discharge were always lower than those of eggs collected from the intake (the mean hatching percentages for all experiments conducted were 26.9% and 46.5% for the discharge and intake, respectively). The disparity was apparently caused by the effects of entrainment through the plant. A Student t-test for paired samples was performed on the results of all experiments conducted. This test indicated that there were significant statistical differences ($\alpha = 0.05$) between the hatching percentages of eggs collected from the plant intake and those collected from the plant discharge.

Table 5.19. illustrates that hatching rates were variable, probably due in part to technical problems, but the results seem to indicate that an inverse relationship exists between hatching success and ambient bay temperature. The highest hatching rates of eggs collected from the plant intake (87.5% and 78.8%) and the plant discharge (46.3% and 45.6%) corresponded to the lowest surface temperatures at the intake (24°C) and discharge (29°C). The lowest hatching rates of eggs collected from the plant intake (4%) and the discharge (0%) corresponded to the second highest surface temperature at the intake (30.5°C) and the highest surface temperature at the

discharge (39°C). Hydrographic data indicated that the average monthly surface temperature ranged from 13.6°C to 29.9°C at the plant intake and from 17.4°C to 38.6°C at the plant discharge during the study period. The relationship between hatching success and ambient bay temperatures would have been more clearly defined had experiments been conducted monthly. Because eggs were not always sufficiently abundant and because of mechanical problems with the collecting boat, monthly experimentation was not always practical or possible.

It should be noted that many species of fish found in Tampa Bay have extended spawning seasons (Springer and Woodburn, 1960; see Chapter V, Part I) and that their eggs and larvae are susceptible to entrainment throughout much of the year. Because of seasonal bay temperature fluctuations, the effects of entrainment may be variable. Since spawning activity is low in the vicinity of the plant during the winter months, fewer eggs and larvae are susceptible to entrainment at this time than during the rest of the year. However, as spawning activity increases during the spring and summer months, the susceptibility of eggs and larvae to damage through entrainment also increases. The eggs and larvae are not only more abundant in the vicinity of the plant, they are also subjected to higher ambient and effluent water temperatures. Rebel (1973) reported on the effects of temperature on the survival of four species of marine fishes from Biscayne Bay, Florida. Two of these species, the scaled sardine, *Harengula jaguana*, and the bay anchovy, *Anchoa mitchilli*, spawn in the vicinity of the Big Bend plant during the summer months. He reported that *Harengula jaguana* eggs and larvae cultured at 35.0°C suffered 100% mortality prior to reaching the pigmented eye stage of development. He also reported that *Anchoa mitchilli* eggs and larvae suffered 100% mortality prior to reaching the pigmented eye stage if cultured at 35.8°C. Big Bend hydrographic data collected from June through September, 1976 (Peekstok, 1976, 1977) indicated that the average monthly surface temperatures ranged from 35.0°C to 38.6°C at the plant discharge (station I-1). Clearly, the survival of eggs and larvae of these species at the plant discharge may be threatened by the high temperatures during these months.

Survival of fish eggs and larvae entrained in power plant condensor systems will depend in part on the length of time the eggs and larvae are exposed to elevated temperatures. The length of exposure time in turn depends on the design of the condensor system. Water entering the Big Bend power plant takes approximately 1.5 minutes to flow through the condensor system and into the discharge canal. Time spent in the discharge canal (and therefore continued exposure to elevated temperatures) is variable due to the amount of effluent discharged by the plant, wind direction and velocity, and tidal stage. Hoss, Hettler, and Coston (1971) conducted experiments to determine the effects of increased temperature on the post-larvae of four fish species. Post-larvae of two of these species, pinfish, Lagodon rhomboides, and spot, Leiostomus xanthurus, are found in the Big Bend area in January and February. Hoss, et al. (1971), reported that 50% of the spot and 17% of the pinfish died three to four hours after being exposed to a temperature 10°C above ambient (15°C). The average monthly surface temperature at the plant intake (station I-6), in January and February ranged from 14.5°C to 18.7°C in 1976 and from 13.6°C to 13.8°C in 1977. The average monthly surface temperature at the plant discharge (station I-1), during the same months ranged from 17.4°C to 18.4°C in 1976 and from 21.6° to 22.3°C in 1977. Entrained post-larval spot and pinfish were not exposed to a 10°C difference between ambient and discharge water temperatures during these months, however, exposure to the elevated temperatures in the discharge canal, possibly for hours, after having been subjected to mechanical shock incurred while passing through the plant could have threatened the survival of these entrained individuals during January and February.

The difference between the mean hatching rates of eggs collected from the plant intake and discharge indicates there is an apparent 42.2% mortality of fish eggs caused by entrainment through the Big Bend power plant. This rate seemingly indicates that local fish populations are being steadily reduced. However, many populations possess a compensatory power sufficient to offset substantial amounts of man-induced mortality (McFadden, 1977). McFadden stated that government regulatory agencies and their scientific staffs involved in power plant licensing proceedings have seemed reluctant to credit many fish populations with significant natural compensatory capacity and have been even more reluctant to make quantitative allowances for this capacity when evaluating power plant impacts. McFadden argued that the repeated removal of 25-50% of a fish population and the sustained reduction of abundance of fish to a level below the pre-fishing stock may seen a drastic proposition, but the practice is a normal and ecologically sound treatment that permits fish stocks to operate at maximum productivity.

To what degree compensation may be occurring in fish populations in Tampa Bay is unknown. In addition, because of the great expanse of Tampa Bay, the transitory nature of many of its different fish species, and the lack of research on its fish populations, the stocks of local fish populations also remain unknown. Since fish stocks and compensatory behavior are at present unknown, the impact of year-round entrainment of fish eggs and larvae on the local fish populations over a long period of time cannot be assessed.

SUMMARY AND CONCLUSIONS

1) A total of eleven rearing experiments, utilizing eggs from both the plant intake (station I-6) and discharge (station I-1) were conducted during the study period.

2) The majority (98.8%) of the eggs cultured were those of the bay anchovy, Anchoa mitchilli.

3) The hatching percentages of eggs collected from the plant discharge were always lower than those of eggs collected from the intake.

4) The results of the experiments seem to indicate that an inverse relationship exists between hatching success and ambient bay temperatures.

5) Fish eggs and larvae are more susceptible to damage caused by entrainment during the summer months than during the rest of the year because of higher ambient and effluent water temperatures and greater relative abundance.

6) Survival of the fish eggs and larvae entrained in the power plant's condensor system will depend in part on the length of time they are exposed to elevated temperatures.

7) Since Tampa Bay fish stocks and their compensatory behavior are presently unknown, the impact of year-round entrainment of fish eggs and larvae on the local fish populations over a long period of time cannot be assessed.

LITERATURE CITED

Blaxter, J.H.S. 1962. Herring rearing. IV. Rearing beyond the yolksac stage. Mar. Res. 1:18 p.

Detwyler, R., and E. D. Houde. 1970. Food selection by laboratory-reared larvae of the scaled sardine, *Harengula pensacolae* (Pisces: Clupeidae), and the bay anchovy, *Anchoa mitchilli* (Pisces: Engraulidae). Mar. Biol. 7:214-222.

Frank, M. L. 1974. Relative sensitivity of different developmental stages of carp eggs to thermal shock. *In* Thermal Ecology. Proc. of a Symposium held in Augusta, Ga., May 3-5, 1973. J. W. Gibbons and R. R. Sharity, eds. U.S. AEC, 670 p.

Hoss, D. E., W. E. Hettler, Jr., and L. C. Coston. 1974. Effects of thermal shock on larval estuarine fish - ecological implications with respect to entrainment in power plant cooling systems. p. 357-371. In: J.H.S. Blaxter (ed.) The Early Life History of Fish: The Proceedings of an International Symposium Held at the Dunstaffnage Marine Research Laboratory of the Scottish Marine Biological Association at Oban, Scotland, May 17-23, 1973. Springer-Verlag. Berlin.

Houde, E. D. 1972. Development and early life history of the northern sennet, *Sphyraena borealis* DeKay (Pisces: Sphyraenidae), reared in the laboratory. U. S. Nat. Mar. Fish. Serv., Fish. Bull. 70:185-196.

Houde, E. D. 1973. Some recent advances and unsolved problems in the culture of marine fish larvae. Proc. World Mariculture Soc. 1972. 3:83-112.

Houde, E. D. 1975. Effects of stocking density and food density on survival, growth and yield of laboratory reared larvae of sea bream *Archosargus rhomboidalis* (L.) (Sparidae). J. Fish. Biol. 7:115-127.

Houde, E. D., S. A. Berkeley, J. J. Klinovsky, and R. C. Schekter. 1976. Culture of larvae of white mullet, *Mugil curema* Valenciennes. Aquaculture 8:365-370.

Houde, E. D., C. R. Futch, and R. Detwyler. 1970. Development of the lined sole, Achirus lineatus, described from laboratory-reared and Tampa Bay specimens. Fla. Dept. Nat. Resour. Mar. Res. Lab., Tech. Ser. 62:1-43.

Houde, E. D., and B. J. Palko. 1970. Laboratory rearing of the clupeid fish Harengula pensacolae from fertilzed eggs. Mar. Biol. 5:354-358.

Houde, E. D., W. J. Richards, and V. P. Saksena. 1974. Description of eggs and larvae of scaled sardine, Harengula jaguana. NOAA, Fish. Bull. 72(4):1106-1122.

Houde, E. D., and L. J. Swanson. 1975. Description of eggs and larvae of yellowfin menhaden, Brevoortia smithi Hildebrand. NOAA, Fish. Bull. 73(2):660-673.

Houde, E. D., and A. K. Taniguchi. 1977. Procedures used to culture larvae of marine fishes at the Rosenstiel School of Marine and Atmospheric Science. Report prepared for Environmental Protection Agency. 17 p.

Jones, A. 1972. Studies on egg development and larval rearing of turbot, Scophthalmus maximus L. and brill Scophthalmus rhombus L. in the laboratory. J. Mar. Biol. Ass. U.K. 52:965-986.

May, R. C. 1971. An annotated bibliography of attempts to rear the larvae of marine fishes in the laboratory. NOAA Tech. Rept. NMFS SSRF-632. 24 p.

May, R. C. 1976. Effects of Salton Sea water on the eggs and larvae of Bairdiella icistia (Pisces: Sciaenidae). Calif. Fish and Game 62(2):119-131.

McFadden, J. T. 1977. An argument supporting the reality of compensation in fish populations and a plea to let them exercise it. In Proceedings of the Conference on Assessing the Effects of Power Plant Induced Mortality on Fish Populations held at Gatlinburg, Tennessee, May 3-6, 1977. W. Van Winkle, ed. p. 153-183.

Middaugh, D. P., and P. W. Lempesis. 1976. Laboratory spawning and rearing of a marine fish, the silverside Menidia menidia menidia. Mar. Biol. 35(4):295-300.

Nash, C. E., C. M. Kuo, and S. C. McConnel. 1974. Operational procedures for rearing larvae of the grey mullet. (Mugil cephalus L.) Aquaculture 3:15-24.

Peekstok, R. M. 1976. Hydrographic studies, Chapter 2. In Tampa Electric Company, Twenty-seventh Quarterly report on the Big Bend thermal and ecological surveys. Contains the Twenty-fourth Quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 440 p.

Peekstok, R. M. 1977. Hydrographic studies, Chapter 2. In Tampa Electric Company, Twenty-eighth Quarterly Report on the Big Bend thermal and ecological surveys. Contains the Twenty-fifth Quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 651 p.

Rao, T. R. 1974. Influence of salinity on the eggs and larvae of the California killifish Fundulus parvipinnis. Mar. Biol. 24:155-162.

Rebel, T. P. 1973. Effects of temperature on survival of eggs and yolk-sac larvae of four species of marine fishes from south Florida. Unpubl. M.S. Thesis, Univ. of Miami, Coral Gables, Fla. 53 p.

Richards, W. J., and B. J. Palko. 1969. Methods used to rear the thread herring, Opisthonema oglinum, from fertilized eggs. Trans. Amer. Fish. Soc. 98(3): 527-529.

Saksena, V. P., and E. D. Houde. 1972. Effects of food level on the growth and survival of laboratory-reared larvae of the bay anchovy (Anchoa mitchilli Valenciennes) and scaled sardine (Harengula pensacolae Goode and Bean). J. Exp. Mar. Biol. Ecol. 8:249-258.

Saksena, V. P., C. Steinmetz, and E. D. Houde, 1972. Effects of temperature on growth and survival of laboratory-reared larvae of the scaled sardine, Harengula pensacolae Goode and Bean. Trans. Amer.Fish. Soc. 101(4):691-695.

Schubel, J. R. 1974. Effects of exposure to time-excess temperature histories typically experienced at power plants on the hatching success of fish eggs. Chesapeaka Bay Inst. The Johns Hopkins Univ., Spec. Rep. No. 32-PPRP-4, Ref. No. 73. 11 p.

Shelbourne, J. E. 1965. Rearing marine fish for commercial purposes. Calif. Coop. Oceanic Fish. Inves. Rept. 10:53-63.

Springer, V. G., and K. D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. Fla. State Brd. Conserv. Mar. Res. Lab., Prof. Pap. 1:104 p.

Stepian, W. P., Jr. 1976. Feeding of laboratory-reared larvae of the sea bream _Archosargus rhomboidalis_ (Sparidae). Mar. Biol. 38:1-16.

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CHAPTER SIX

A STUDY ON THE DISTRIBUTION AND ABUNDANCE OF INVERTEBRATE MEROPLANKTON AT BIG BEND, TAMPA BAY (FLORIDA)

By

R. Harry Blanchet
Walter M. Avery
Jay R. Leverone

August, 1977

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LIST OF PARTICIPANTS

PRINCIPAL INVESTIGATOR:	R. Harry Blanchet B.S. Staff Biologist
RESEARCH ASSISTANTS:	Walter M. Avery B.A. Staff Biologist
	Jay R. Leverone B.A. Staff Biologist
	Joseph D. Murdoch M.A. Staff Biologist
	Daniel Page II B.S. Staff Biologist
	Robert Whitley Marine Science Technician

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INTRODUCTION

General

The invertebrate meroplankton form a unique and important part of the zooplankton. As larvae, they are subject to the vagaries of a planktonic existence, while as adults they constitute a major portion of the benthic fauna. This study is concentrated on the larvae of the decapod crustacea. Adult decapods are an important fraction of the macrofauna, and their life histories are well known. Their larvae are a distinctive and widespread part of the plankton.

The study of meroplankton in the vicinity of the Big Bend electric generating station was initiated in January, 1976 and sampling continued through March, 1977. Sampling design and program objectives were outlined in the Addenda to Prospectus for Ecological Studies at Big Bend Steam Electric Station (Tampa Electric Station), a 316 Demonstration (TECO, 1975) and in conferences with representatives of governmental regulatory agencies (U.S. Environmental Protection Agency, State of Florida Dept. of Environmental Regulation). Specific objectives of the study have been to:

1. identify and enumerate selected meroplankton at source and receiving water stations;
2. calculate numbers of these organisms entrained.

Project Review and Limitations

This project is basically a survey of the meroplankton in the waters around the power plant. Although estimates of entrainment are presented, assessment of the impact of the plant upon the populations involved was not within the scope of this study. There is very little data available on the magnitude of the adult populations producing the larvae, the fecundity of the adults, and the frequency of spawning of individual breeders. There is insufficient data on the current patterns in the area to allow estimation of the areal extent of the populations whose larvae are susceptible to entrainment or which might be affected by drift into the thermal area. The effect of rapid temperature changes on larvae has not been studied. Although some studies on the effect of temperature and other factors on larval survival have been conducted (Costlow and Bookhout, 1962, 1971; Costlow, Bookhout and Monroe, 1966, others) most of this work has been done at higher latitudes than Tampa Bay.

Our more tropical populations might have different tolerances from their mid-Atlantic counterparts. These studies do tend to show that larval decapods can not only tolerate relatively high temperatures (about 30-35°C) but can sometimes flourish at these temperatures. Other factors can influence these results, e.g. sub-optimum salinity for the species tends to lower the thermal tolerance in the species studied. Diurnal temperature fluctuations of 5° or 10°C, on the other hand, tend to raise the survival rate at high temperatures. Rapid temperature rise, as through power plant entrainment, would, of course, subject the organism to a great deal more stress than would gradual diurnal fluctuations.

No effort has been made to quantify mortality from entrainment in this study. Other studies on zooplankton entrainment have found anywhere from 0 to 100 percent mortality (Lauer et al, 1975). This variable mortality is dependent on intake and outfall temperatures, temperature rise, salinity, and the life stage of the individual organisms involved. Other factors such as food availability, pollution by pesticides, organic wastes or heavy metals, availability of oxygen, and plant design and operation (hydraulic stresses, rapidity and duration of the temperature rise, presence or absence of biocides, etc.) may also affect mortality (Cairns et al., 1975; Clark and Brownell, 1973; Vernberg and Vernberg, 1974; Vargo and Sastry, 1977).

Few published studies have treated meroplankton in any detail. Sandifer (1973) has produced the most complete work to date on the decapod larvae, and also presents a review of the work to that time. His more recent paper (Sandifer, 1975), has helped delineate the roles planktonic stages play in the life histories of the species.

Tagatz (1968) reported several species of crab zoea from the St. Johns River, but most of the data on breeding populations of decapods in Florida came from records of ovigerous females encountered in studies of the adults. These studies (Wass, 1955; Tabb and Manning, 1961; Williams, 1965; Rouse, 1969; Lyons et al, 1971) show two breeding patterns along the coast of Florida. Northern Florida animals generally breed through the warmer months, while the southern Florida crustaceans show year round breeding, with more species breeding in fall, winter, and spring than during the mid-summer.

In their study of Tampa Bay macrozooplankton, Kelly and Dragovich (1967) used a large (1.024 mm) mesh net which allowed most types of early decapod larvae to pass through, though it did retain penaeid postlarvae, porcellanid crab larvae, and later zoea of some other forms. Quantitative comparison with the present study is therefore inappropriate for most forms.

In terms of total numbers, the decapod crustaceans compose a rather small portion of the meroplankton. Kelly and Dragovich (op cit.) found much of their plankton to be crustacean meroplankton. Their large mesh net did not capture most of the smaller forms which compose a majority of the meroplankton. Hopkins (1966) reported that decapod larvae averaged only some 2.5% of the larval forms collected with a #10 mesh (155 μ mesh diagonal) net. Even with this net, he found that pelecypod veligers were not quantitatively sampled, as most were even smaller than this mesh size. Comparative tows with a #20 mesh (99 μ diagonal) showed nearly five times the number of these veligers as the #10 mesh samples.

METHODS

Samples taken for the ichthyoplankton program were also utilized for meroplankton studies. Sampling methodology (oblique tows with a 1 m diameter 363 μ mesh net) is discussed in the ichthyoplankton section of this report (Chapter 5). Station locations are shown in Figure 5.1 in that section. This sampling design was suggested and approved by the regulatory agencies. Supplementary oblique (January-March, 1975) and vertical (April, 1976- February, 1977) tows were taken with a 30 cm or 50 cm #20 mesh (75 μ bar mesh) net.
These tows were used for qualitative observation of the smaller

meroplankton present. In addition, mollusk veligers and brachiopod larvae were also counted when encountered in the phytoplankton samples.

Samples were sorted using an Olympus TM300, and Bausch and Lomb Stereozoom and Stereozoom 7 dissecting microscopes. Final identifications were normally made using the B and L Stereozoom 7. Certain fine details were checked using a B and L Dynazoom compound microscope. After thoroughly agitating the sample, aliquots of the samples were taken using 10 ml capacity Tippet dispensers. All decapod crustacean larvae were removed from the sorting dish and placed in numbered vials. Specimens of the other taxa were also held for reference, but most of these specimens were counted without picking them out. Aliquots were taken and sorted until at least 200 decapod larvae were counted. All aliquots were sorted completely. If fewer than 200 decapods were found, the entire sample was counted.

During the warm months, meroplankton abundance was very high. Samples with high numbers of meroplankton were sorted in the usual manner, but in addition, an extra set of aliquots was sorted. For the second set, decapod species with over 30 individuals represented in the first set (i.e. the dominant species) were not counted. Aliquots were taken until at least another 100 decapod larvae were sorted and identified. Usually no forms other than decapods were counted from the second set of aliquots. Data was stored in the computer as raw counts to facilitate corrections. Conversion of the data was made to numbers per cubic meter and these values were used for analytical procedures and interpretation of abundance levels.

Identification

An artificial key to the larval decapod crustacea of the Big Bend area is presented in Appendix 6A. It includes a bibliography of the literature used to identify decapods in this project. Many other works were consulted from time to time, but were not of direct use in identification and thus are not included.

In recent years, the identification of decapod larvae to species or genus has been simplified by the many studies in which larvae have been reared in the laboratory from the first zoea through metamorphosis (see Appendix 6A). Before these rearing techniques were established, larval identification relied solely on the study of larvae from the plankton. In these cases, the first stages were hatched from gravid females. Late stage larvae from the plankton were held through metamorphosis into the juvenile form. Intermediate stages were described from similar larvae found in the plankton. This method must be used with caution, as larvae of similar species might not be distinguished.

Identification of larvae preserved from plankton samples may present some problems even if the species has been described, since the pigmentation fades fairly rapidly and this major aid to identification becomes useless. This is especially important with damaged specimens where some other character might also be useless. While many forms of decapod larvae have been described, some species inhabiting Tampa Bay are still undescribed. Some of these are recorded as unknown species (i.e. Brachyura sp. A), but it is possible that some undescribed form might have been confused with another species within the same genus or sub-family. Thus, genera with both known and unknown forms present might only have the described form recognized. This is because it is impossible to give each individual the intense study necessary to check all the diagnostic features of the species (especially setation of the endopodites of the maxillipeds and mouth parts).

Many of the caridean shrimp have been examined by Dr. Sheldon Dobkin of Florida Atlantic University to verify our identifications.

RESULTS AND DISCUSSION

General

Total meroplankton as sampled by the 363 μ mesh net showed two peaks of abundance, one in April and the other in October (Figure 6.1). Decapod larvae accounted for 94% of the larval forms recorded overall. Only in the coldest months, when decapod larvae were rare, did other larval types make up a large proportion of the catch.

A total of 105 taxonomic groups were recorded in the 363 μ mesh net samples (Appendix 6B). These included 86 of decapod crustacea taxa and 19 miscellaneous forms of 7 phyla (including Arthropoda). Some 38 decapods were recognized to species while 24 other forms were found which were assigned to arbitrary specific names according to varying higher taxonomic orders (e.g. *Pinnixa* sp. B, Alpheidae sp. A, Brachyura sp. A) and 24 forms were recognized only to genus or family. Those identified to genus or family only included some forms of damaged larvae whose identity were uncertain, and postlarvae with the adult characters not discernable. Others were genera within which species differences could not be discerned (i.e. *Uca* spp.).

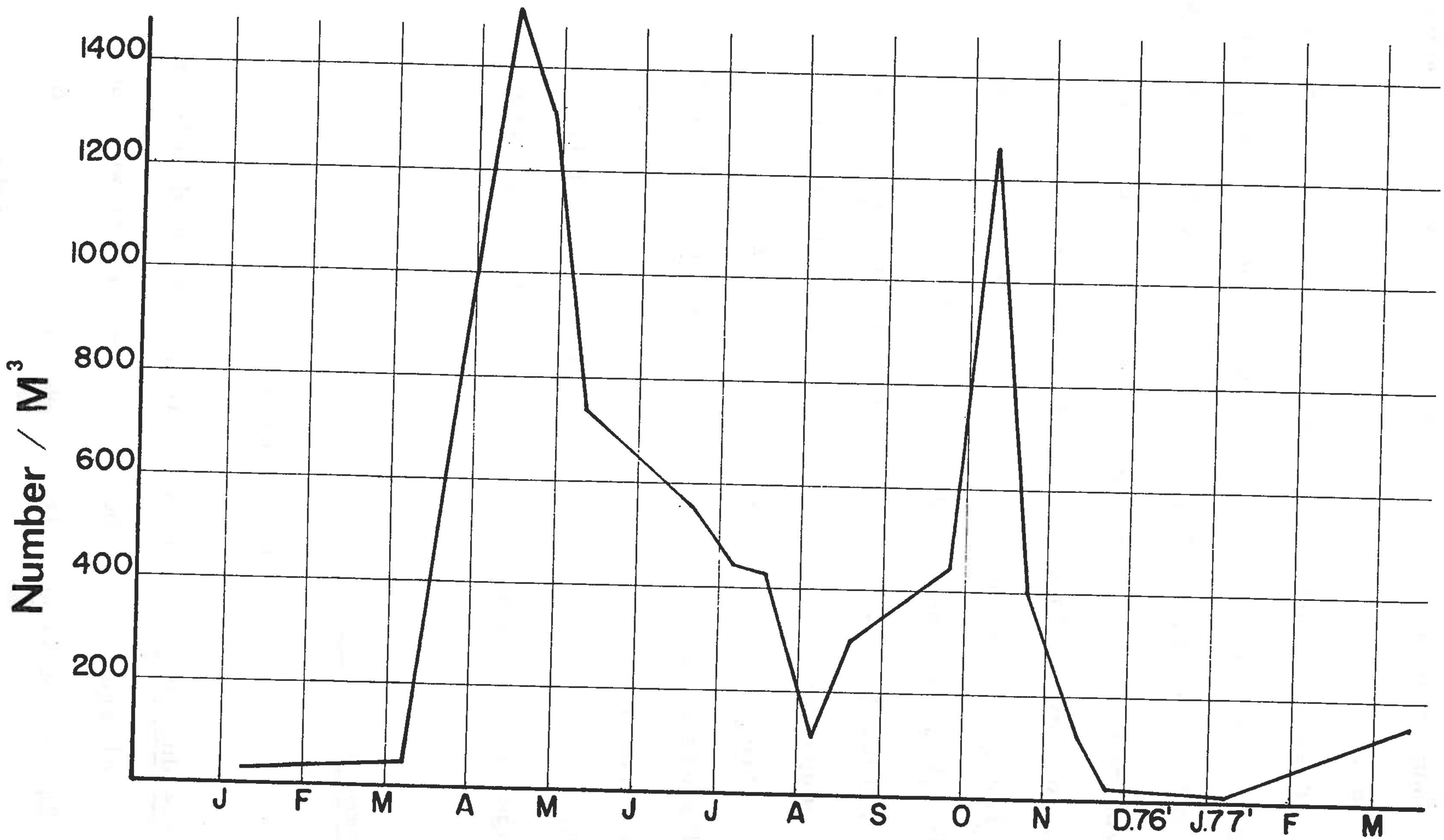


Figure 6. 1. Total meroplankton abundance, average of all Big Bend stations (day and night) over the study period.

Forms other than arthropods were identified only to the major taxonomic level.

A list of species and abundance at each station for each sampling period has been presented in the quarterly reports (Blanchet, 1976 a and b, 1977 a and b; Avery, Leverone & Blanchet, 1977). These reports present the data for each species without respect to larval stage. The data by stage was too voluminous for inclusion in the reports. Persons with an interest in this data can obtain it from Conservation Consultants, Inc. (P. O. Box 35, Palmetto, Florida 33561).

The average daytime water temperatures for some representative stations are presented in Figure 6.2. For more detailed discussion of physical parameters, refer to the Hydrographic section of this report. (Chapter Two).

The following discussion is intended as an outline of the findings of the meroplankton samples taken over the study period.

Species Composition and Seasonal Abundance

Penaeid Shrimps

Penaeus duorarum, the pink shrimp, was found only in the late postlarval stages. Numbers of this species were quite low; only 24 specimens were found during the entire study. Of these, only one was captured in the daytime (October 9 sample).

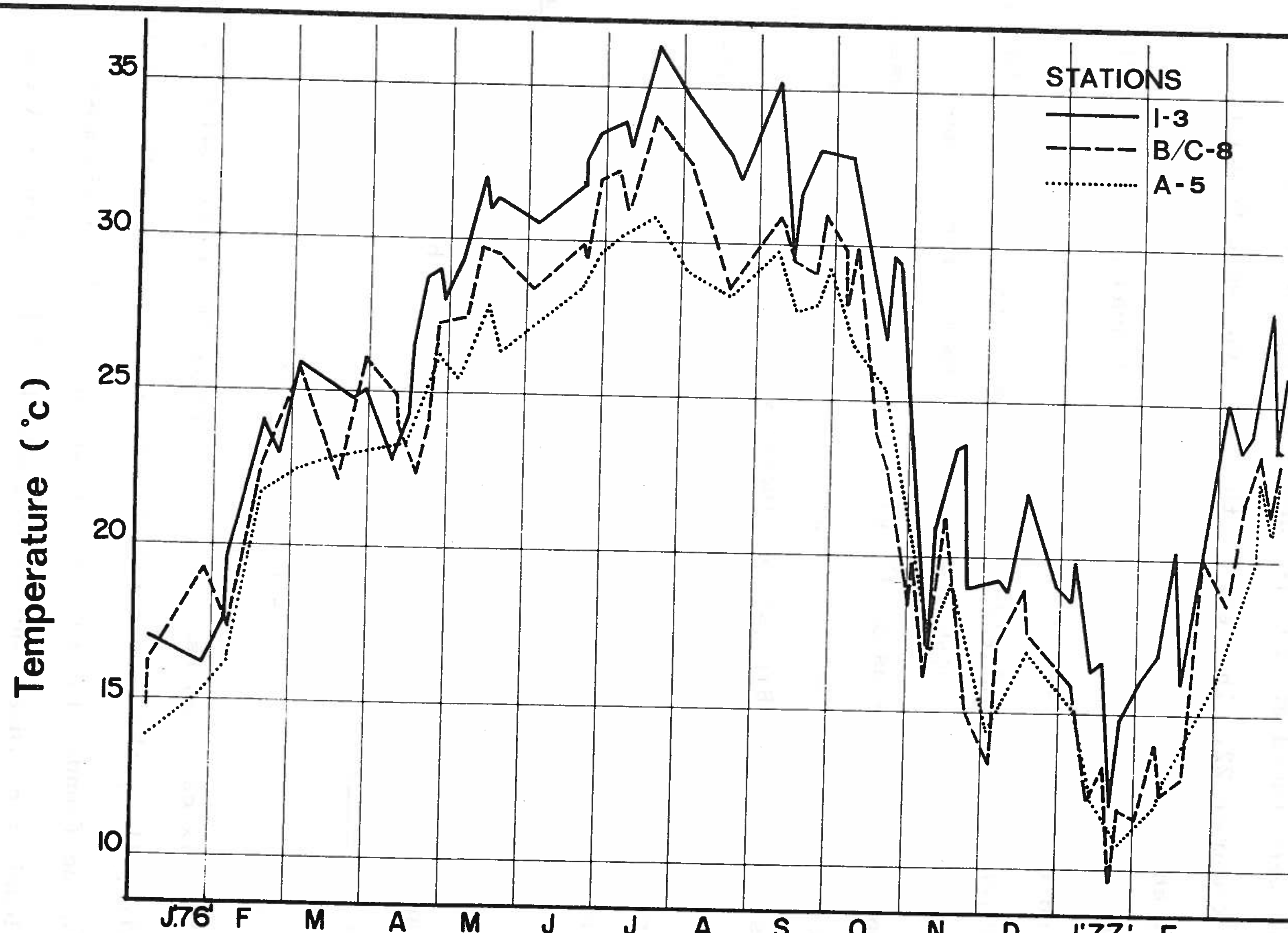


Figure 6. 2. Average daytime water temperature from plankton and hydrographic sampling at the point of discharge (I-3), thermal (B/C-8) and control (A-5) stations.

Three were found at the discharge, in samples from October 22 and November 22. The rest of the specimens were found in July and August samples from several stations, the greatest number (11 total) from station B/C-8. Thorhaug et al. (1971) found the thermal death point (LT100) of the first and second postlarval stages of pink shrimp to be approximately 38° (died within 2.5 hours), with some mortality to the first stage at temperatures as low as 34.9°C with longer experimental exposures (25 hours). Second stage postlarvae were not tested past 2.5 hours. Big Bend effluent temperatures were above 35°C for much of July, August, and September, and entrained post-larvae were probably significantly stressed throughout this period.

A single damaged penaeid postlarva, probably *Trachypenaeus* or *Sicyonia*, was found in the daytime discharge sample on August 3. This was the only penaeid found other than *P. duorarum*.

Caridean Shrimps

Six caridean families were represented in our samples. Altogether, they represented approximately 5% of the decapod larvae found. The seasonal distribution of the six most abundant caridean shrimps is summarized in Figures 6.3 and 6.4. Though larvae of these species were found year round or nearly

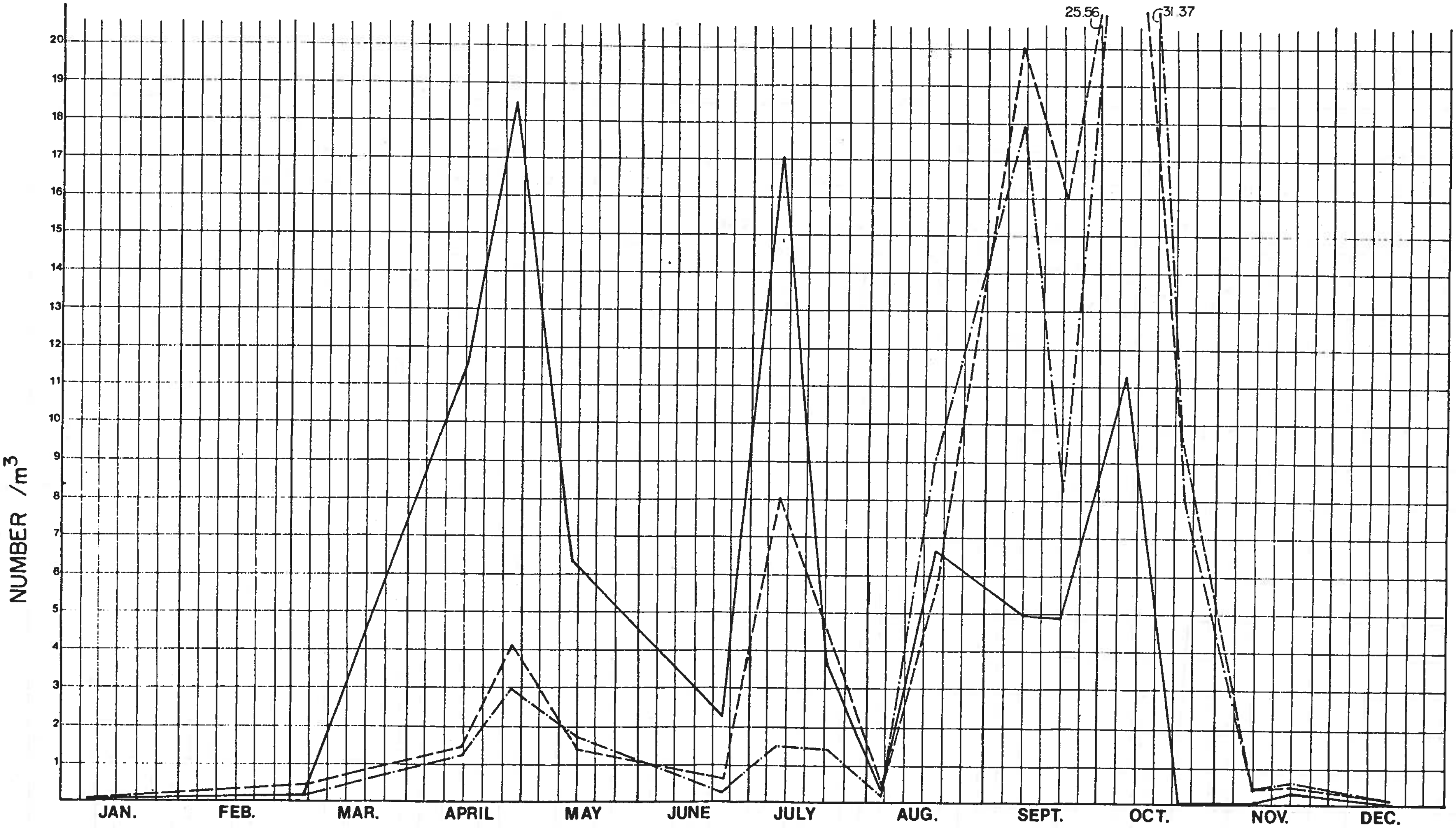


Figure 6.3. The average number per m^3 of the larvae of three caridean shrimp species from January, 1976 to March, 1977 at Big Bend. (--- *Ambidexter symmetricus*, —— = *Alpheidae* sp. A, —·—·— = Periclimenes spp.).

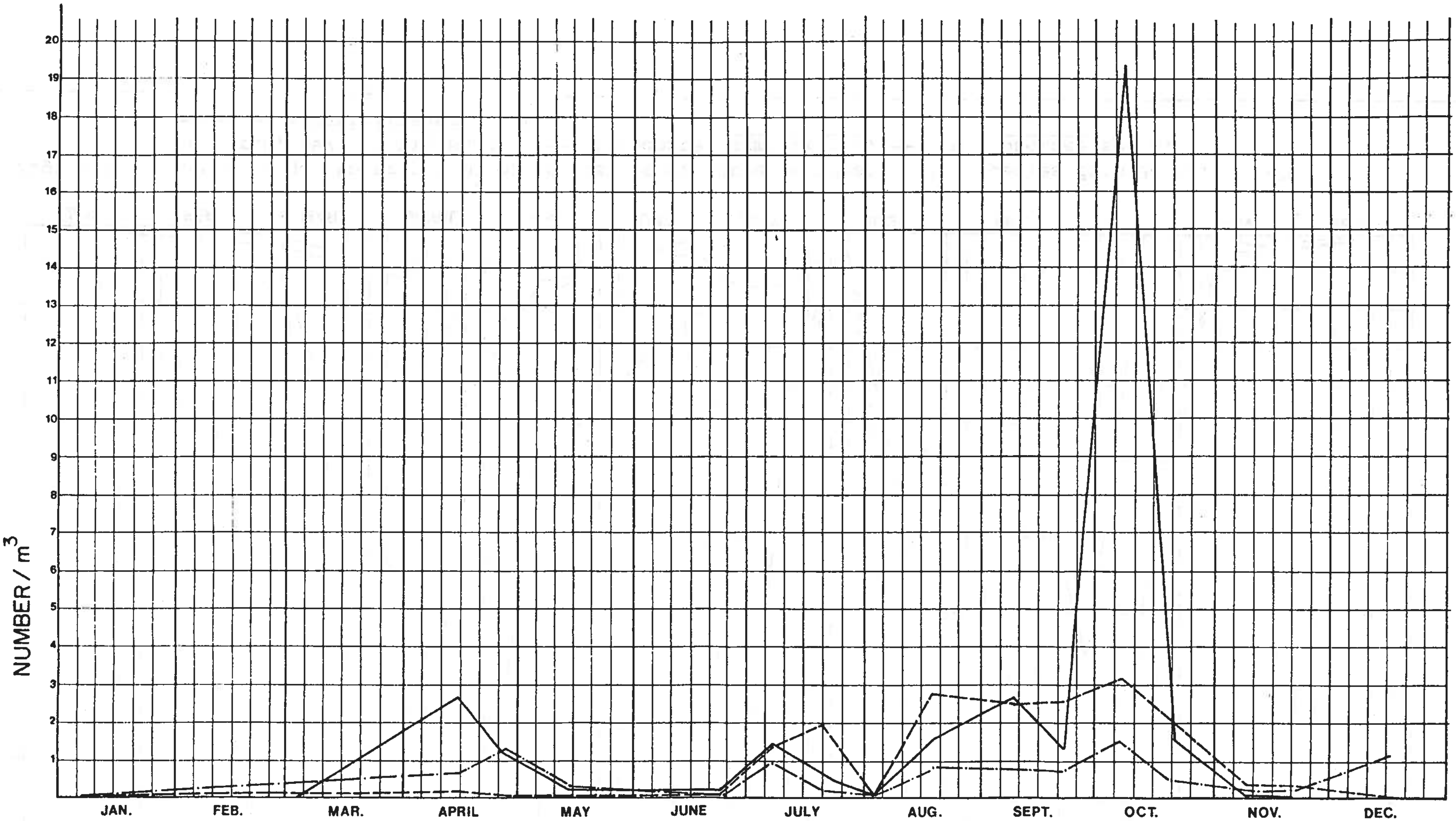


Figure 6.4. The average number per m^3 of the larvae of three caridean shrimp species from January, 1976 to March, 1977 at Big Bend (--- = Ogyrides limicola, —— = Latreutes parvulus, —·—·— = Hippolyte spp.).

so, there are generally one or two strong peaks in abundance. Our abundance figures are presented as an average of the 20 stations (10 day, 10 night) for each sampling period, however, high variation did exist between stations.

The most abundant caridean overall has been tentatively identified as Ambidexter symmetrius (Processidae). The larvae of this species have not been previously described, but are easily distinguished from larvae of Processa, the only other genus reported as an adult in the vicinity. The identification of this larva as Ambidexter is based on a series of eight zoeal stages and postlarvae taken in the plankton during this study. As in other processids, the bases of the antennules are well separated, but the antennules are curved so that one third along their length they are separated only by slightly over half the width of the antennule. In other processids the antennules remain separated by more than their width. More complete description of this larval type (appendage setation patterns, etc.) was not possible due to the time limitations and scope of this project, but hopefully will be pursued at a later date. Figure 6.3 shows the occurrence of Ambidexter larvae through 1976. The major spawning peak coincides with that of Periclimenes spp. Palaemonidae Larvae of Processa spp. were also recorded in low numbers mostly from August through

December (greatest numbers in October).

Although no species were identified, five forms of larvae were assigned to the family Alpheidae. The most abundant form, Alpheidae sp. A, is probably of the genus Alpheus (Dobkin, pers. comm.). Its seasonal distribution is shown in Figure 6.3. Larval abundance indicates three breeding pulses between April and the middle of October. More second stage zoea were found than first stage on every sampling date in this period. First stage outnumbered second stage in March and November samples, but abundance of all stages was low at these times (1-3/m^3 total). Although we have not attempted to measure the duration of each stage, many rearing studies of other decapods report approximately equal lengths to the zoeal stages within a species. The abundance of second stage zoea suggests that a significant portion of the larvae of this species comes from outside the study area (assuming each stage is of similar duration). Larvae from areas external to the study area would be older when they drifted into the area than larvae produced locally, and would more likely be recruited at some stage after stage I zoea.

Alpheidae sp. A. was more than ten times as abundant as the next most common alpheid.

Periclimenes spp. was the most abundant palaemonid shrimp. Its seasonal distribution is summarized in Figure 6.3. Periclimenes americanus and P. longicaudatus were found as postlarvae in our samples and as adults in the otter trawl (see Chapter 8) and the benthic grab (see Chapter 4) samples in the area, with P. americanus seemingly more common. No attempt was made to distinguish these species; the larvae were very similar. P. americanus was hatched out, but no ovigerous P. longicaudatus were found for direct comparison of specimens, and there were no distinguishing characters between laboratory hatched larvae and those from the plankton to help separate the two forms. Lyons et al. (1971) found ovigerous P. americanus from May through September, while Tabb and Manning (1961) found them in October and December through April, and Rouse (1969) recorded ovigerous specimens year round, most prevalent in March and April. Rouse (op cit.) also recorded P. longicaudatus as breeding from September through April, but mainly in February and March. From our samples, the main breeding season in the Big Bend area is from August through October. First stage zoea were still relatively common (five per m^3) in the samples from October 21, indicating that breeding persisted at least until then.

The family Ogyrididae was represented by larvae identified as Ogyrides limicola. O. yaquiensis is known to occur in

Florida south of Tampa Bay (Rouse, 1969). Chace (1972) suggested that these two forms might be variations of a single species. Larval development of *O. yaquiensis* has not been described, and such a study might help elucidate the relationship of these two forms. No differences were noted, however, between our larvae and *O. limicola* as described by Sandifer (1972). Occurrence of *Ogyrides* larvae is presented in Figure 6.4. The large peak on October 7 is due to very large numbers of larvae found at the discharge and at the open bay control stations E-5, B/C-5 and A-5.

Larvae of *Latreutes parvulus* and *Hippolyte* spp. accounted for most of the hippolytid specimens in the samples. *Hippolyte* larvae were found year round in low numbers, while *L. parvulus* was most common from July through October (see Figure 6.4).

The family Pasiphaeidae was represented by larvae of *Leptochela* sp. (probably *L. serritorbita*) which was found in low numbers in samples from August to January (highest in October).

Macruran Shrimps

The family Callianassidae was represented by four larval types of *Callianassa* spp. in low numbers, and by *Upogebia affinis*. *Upogebia* larvae were the third most abundant larval type found. Seasonal distribution of the larvae by stage is shown in Figure 6.5. There is some indication in the August 18 samples that breeding may have started again outside the study area somewhat more rapidly than within the area, after the mid-summer depression, shown by the abundance of second and third stage zoea in these samples. Sandifer (1973) reported most specimens as occurring above 23°C, with peak abundances at 25-27°C. This correlates well with our findings, though Sandifer (op cit.) found his largest numbers from June to October, while our highest numbers were found in spring and early summer samples.

Two larval specimens provisionally identified as Naushonia sp. (N. portoricensis?) of the family Laomediidae were found. One third stage larva was found on October 21 in the daytime sample from the intake (station I-6). A damaged stage V (?) was found at station O-8 on September 23 in the daytime. These larvae fit the description of Gurney and LeBour (1939) from Bermuda specimens in most respects, but they lack the pleural hooks on the first abdominal segment. This is the first record of this genus from the Gulf of Mexico (Dr. Anthony J. Provenzano, Jr., Old Dominion University Institute of Oceanography, Norfolk, Virginia, personal communication July 12, 1977).

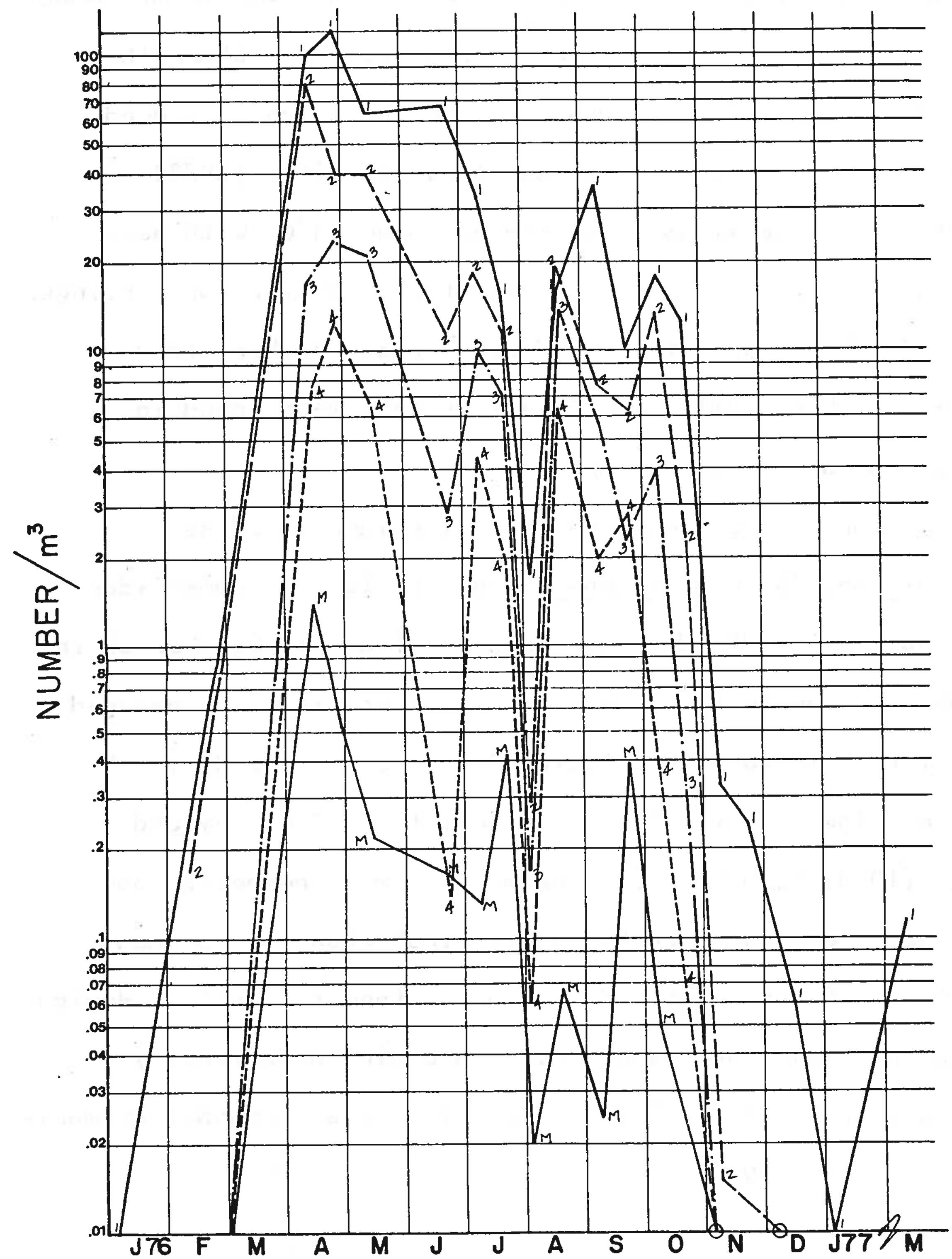


Figure 6.5. The average number per m^3 of the larval stages of Upogebia affinis from January, 1976 to March, 1977 at Big Bend. An open circle indicates <0.01 per m^3 average.

Anomuran Crabs

Larvae of *Polyonyx gibbesi* (family Porcellanidae) were the second most abundant larval type in our samples. Seasonal distribution of these larvae by stage is shown in Figure 6.6. Abundance of the larvae was quite variable between stations; large swarms were noted throughout the area during the warm months. They were abundant enough to become matted on the travelling screens of the plant intake (see Impingement section, Chapter 7). These mats were composed of both first and second stage zoea, with the second stage predominating. This larva was one of the few species which was commonly found to be more abundant in intake than discharge samples. This may have been due to the removal of the larvae by the screens, or some other unknown factor. Sandifer (1973) found most of his larvae of *P. gibbesi* in bottom tows, but we have observed many swarms of these zoea near the surface in the daytime. Though swarms are not so easily seen at night, they were noted occasionally.

More *P. gibbesi* larvae were found in daytime samples than at night in all samples in which they were abundant, except on September 22 when both zoeal stages were more abundant at night.

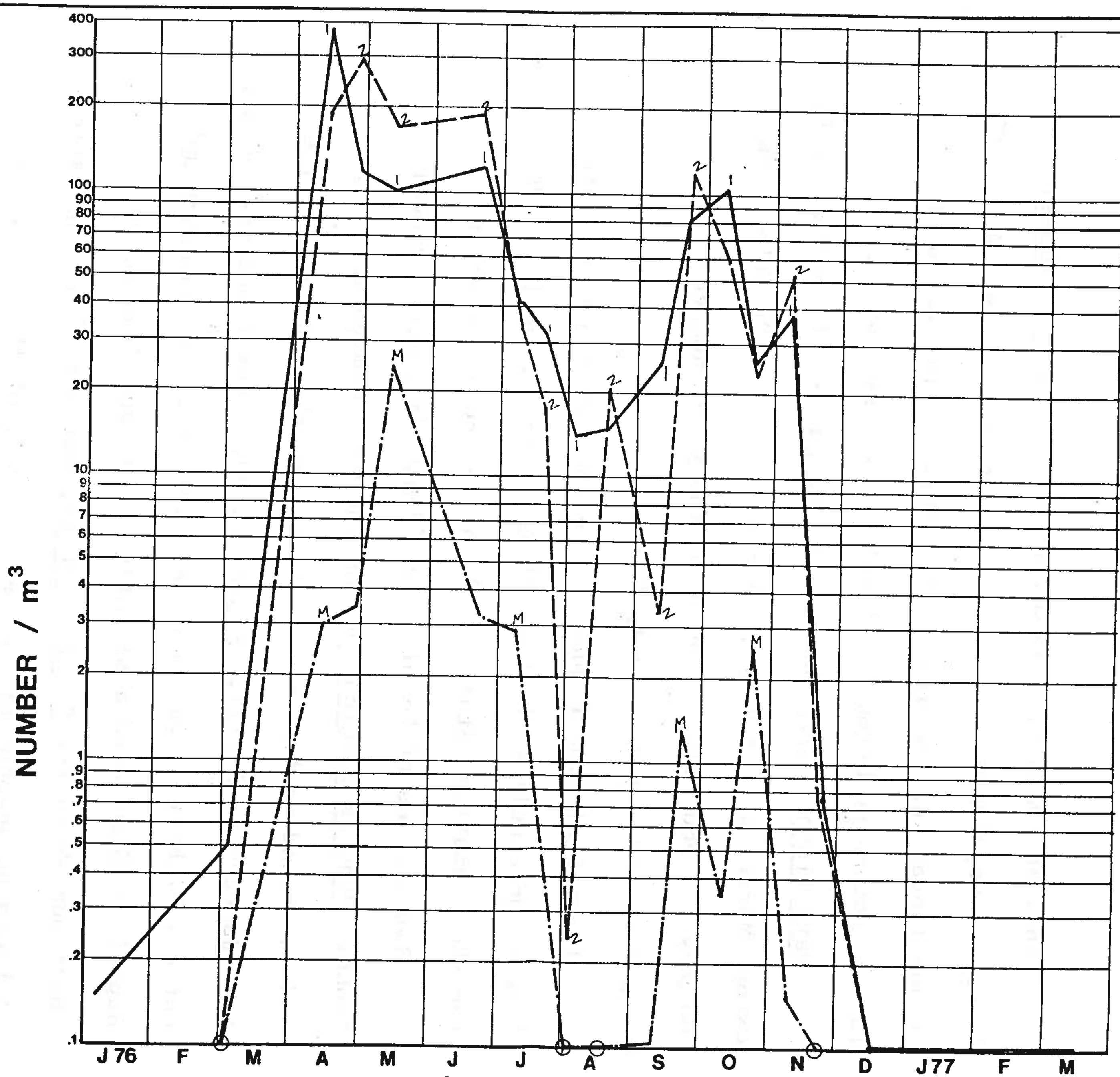


Figure 6.6. The average number per m^3 of the larval stages of Polyonyx gibbesi from January, 1976 to March, 1977 at Big Bend. An open circle indicates <0.01 per m^3 average. (1-2 = Zoeal Stages 1-2, M = Megalops Stage)

Sandifer (op cit.) found some 10% of his _P. gibbesi_ larvae as megalopae, nearly all in bottom samples. About 2% of our larvae were megalopae, but this may be due to the larvae occurring below the level sampled by the net.

Petrolisthes spp. larvae were found in all months sampled except March, but were very rare in November, December, and January. Throughout the rest of the year, numbers of zoea were low, and megalops rarely found.

In general, our figures for abundance of porcellanid larvae agree well with those of Kelly and Dragovich (1967) for their station (Station 13) in the present study site.

Two species of hermit crab (Paguridae) were commonly found. _Pagurus longicarpus_ was the more common species, and was found mostly from late October through April (highest from January to April). Paguridae sp. A was found year round but was highest in September and October. Fogeringham and Bagwall (1976) found a slightly longer breeding season (September-May) for _P. longicarpus_, but a similar separation of breeding seasons of the hermit crabs of the northeast coast of Texas.

Brachyuran Crabs

Larvae of a leucosiid crab tentatively identified as _Persephona aquilonaris_ (see Blanchet, 1976b) were found in samples from all months except January. Four zoeal stages and a megalops were recorded. Larvae were common from April through August, with the highest numbers in April samples.

Six species of xanthid crabs were common to abundant as larvae in the samples. Their seasonal pattern of occurrence is presented in Figure 6.7.

Rithropanopeus harrisi zoea were most abundant at slightly cooler temperatures than other xanthids and were almost entirely absent from the warmest part of the summer. Though following the other four species (Neopanope texana, Hexapanopeus angustifrons, Panopeus herbstii and Menippe mercenaria) in spawning during the April and September seasons, Eurypanopeus depressus larvae did not show the mid-summer spawning peak, but remained relatively low. The other four species presented showed similar patterns of abundance, with three spawning peaks in April, July, and September-October.

Menippe mercenaria was common from April through October, but was never abundant. First stage larvae were far more numerous than any other stage, and comprised some 78% of the specimens found. In contrast, 51% of the Neopanope texana larvae found were stage I zoea. Thorhaug et al. (1971) found thermal death points for Menippe zoea to be between 33° and 36°C, and for the zoea/megalops molt to be near 31°C. Big Bend effluent temperatures from the middle of May until the

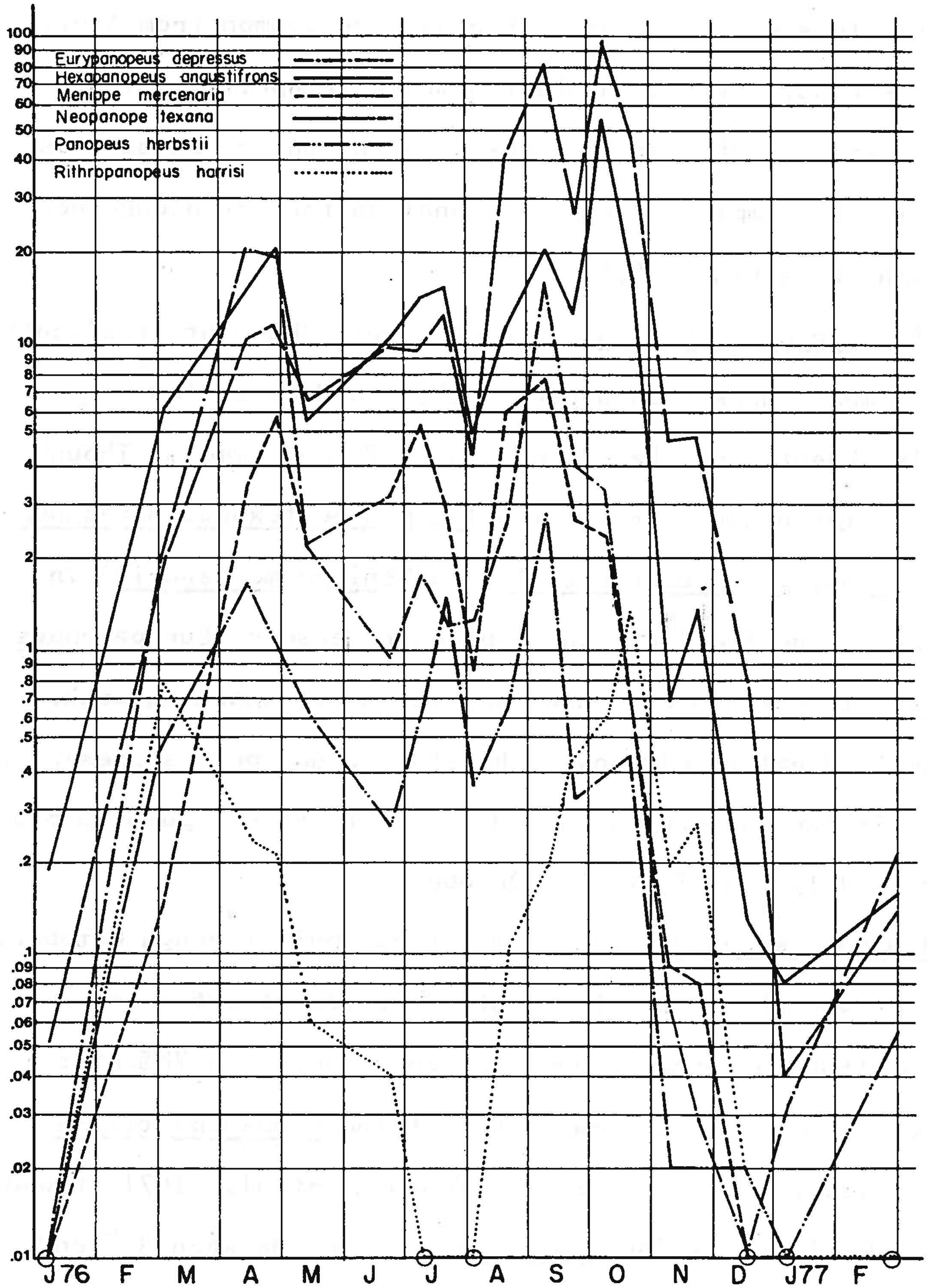


Figure 6.7. Abundance of the six most common types of xanthid crab larva in the Big Bend area, January, 1976 to March, 1977. An open circle indicates $\angle 0.01$ per m^3 average.

middle of October probably would stress the zoea of this species. Even ambient bay temperatures would seem to affect the molt to the megalops through the hottest part of the summer (see intake temperatures in the Hydrographic chapter).

Neopanope texana and Hexapanopeus angustifrons were the most abundant xanthid species overall, and the fourth and fifth most abundant decapod species. Their larval abundances by stage are presented in Figures 6.8 and 6.9. In both species the late summer/fall breeding season was the strongest, and seems to be bimodal.

Rouse (1969) found Neopanope texana to be ovigerous in the winter, while Lyons et al. (1971) found that the species bred from February to October.

In southwest Florida, Hexapanopeus angustifrons was ovigerous year round, but most commonly between February and July (Rouse op cit.). In Chesapeake Bay, Sandifer (1973) found the larvae from June to October [highest numbers reported in August (25-26°C)]. In North Carolina Williams (1971) found the abundance of megalops highest in August and September. The megalopae found in the present study were often damaged. Problems in distinguishing between the larvae of H. angustifrons and N. texana at this stage were common. The relative abundances of the two species at this stage is subject to some error because of this problem.

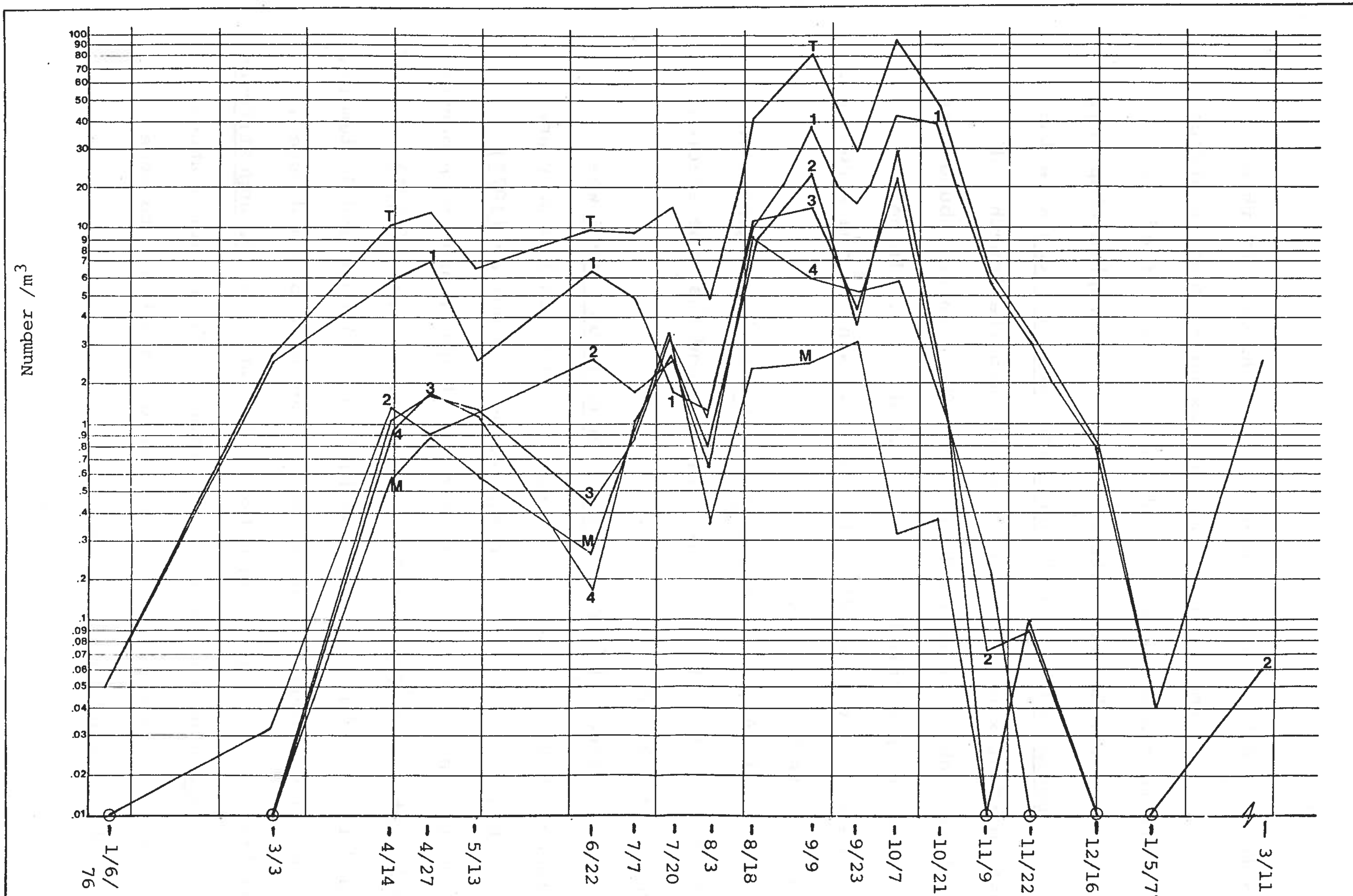


Figure 6.8. Abundance of the larvae of Neopanope texana by stage in the Big Bend Area, January, 1976 to March, 1977. (1-4 = zoeal stages 1-4, m = megalops stage, T = Total Numbers). An open circle indicates <0.01 per m^3 average.

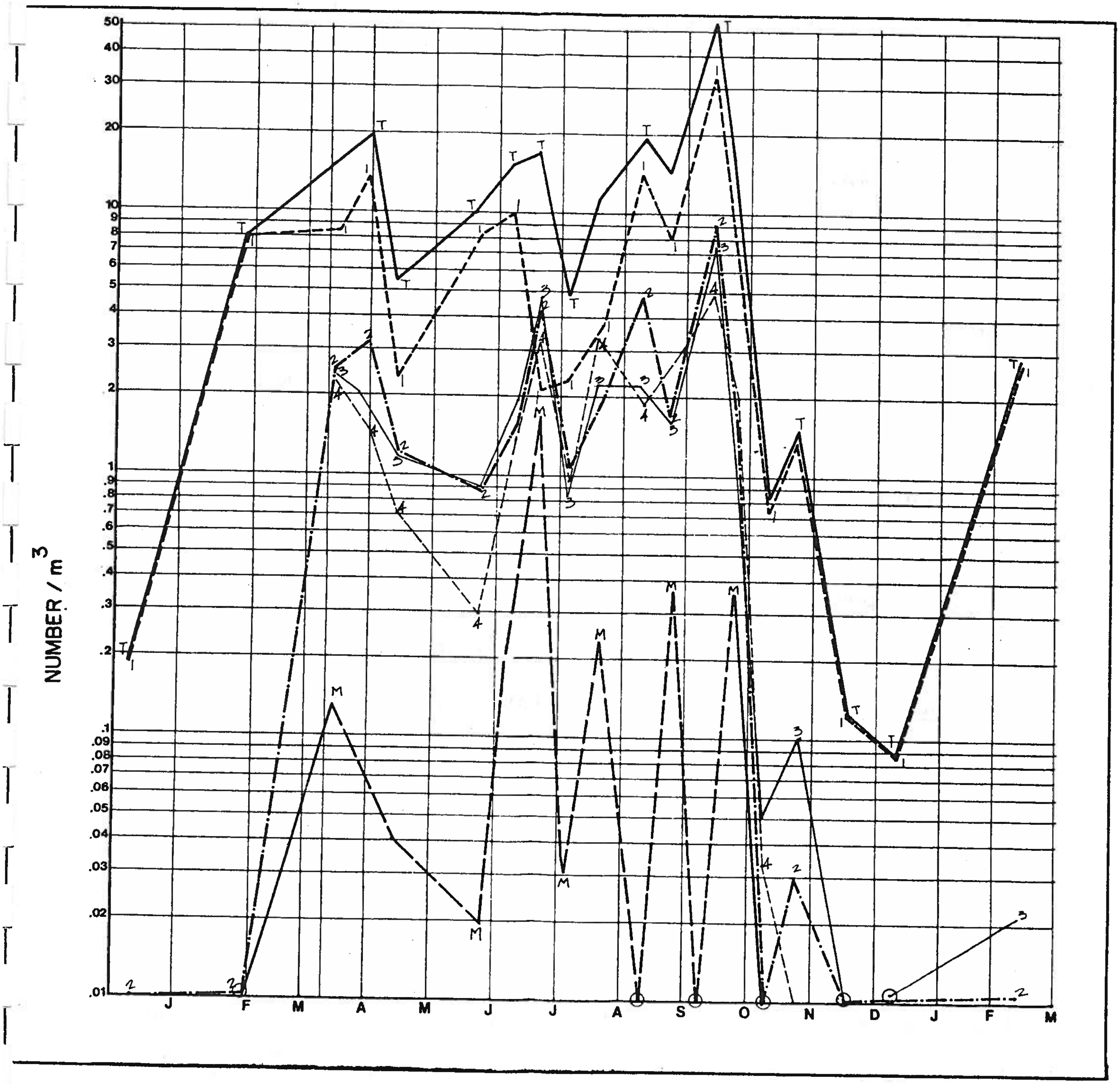


Figure 6.9. Abundance of the larval stages of <u>Hexapanopeus</u> <u>angustifrons</u> in the Big Bend area, January, 1976 to March, 1977. An open circle indicates $<$ 0.01 per m^3 average. (1-4 = zoeal stages 1-4. M = megalops stage, T = Total Numbers).

Both *N. texana* and *H. angustifrons* had unusually high relative abundances of late stage larvae in some mid-summer samples. The large numbers of late stage zoea relative to the stage I in the July 20 samples indicate a recent, rather abrupt end to the production of larvae in the area. In August 18 samples, stage I zoea were still rather low, while later zoea increased well over the previous samples' level. These later stage zoea were probably produced outside the study area and were carried into the area by currents, as the low numbers of stage I zoea indicated that breeding within the area was still at a low level.

Pinnixa sayana was the most abundant decapod in the samples. Its seasonal distribution is shown in Figure 6.10. Two major spawning peaks were found, in April and October, with a smaller peak in July. As with *Neopanope texana* and *Hexapanopeus angustifrons* larvae, later stage zoea were more abundant than stage I just previous to and at the end of the mid-summer depression in breeding. Stages III and IV also show high values relative to stage I in May 13 samples, after the spring spawning peak. The abundance of the postlarval stage of *P. sayana* is presented, but may not be accurate, as this stage may not be constantly pelagic. The gross morphology of the stage certainly suggests a benthonic existance, as the body shape and the form of the abdomen and perieopods do not

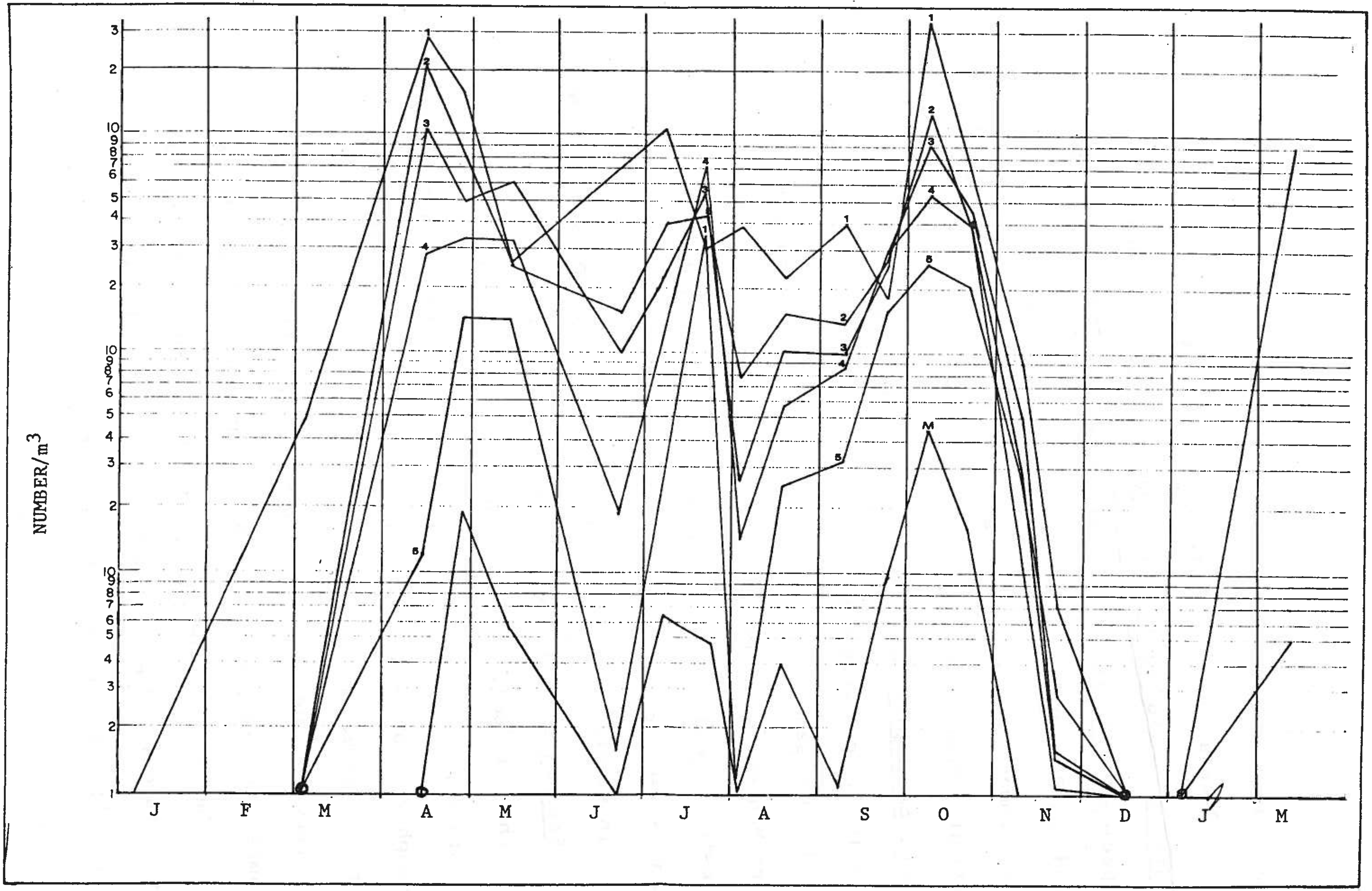


Figure 6.10. Abundance of the larval stages of Pinnixa sayana in the Big Bend area January, 1976 through March, 1977. An open circle indicates <0.1 per m^3 average. 1-5 = zoeal stages 1 through 5. M = megalops stage.

seem adapted for swimming.

Several other pinnotherid species were found, including *Pinnixa chaetopterana*, *Pinnotheres maculatus*, unknown species of *Pinnixa* (sp. A and sp. B) and *Pinnotheres* (sp. A and sp. B). *Pinnixa chaetopterana* was found year round, and was common from April through October. *Pinnotheres maculatus* was also most common in this period, but was not as abundant as *P. chaetopterana*. Other pinnotherid species were rare, and in general were found only from April to October at Big Bend. The same species were more common in samples from the Port Manatee area (Blanchet, 1976c), where salinity, substrate, and other factors may be more favorable to these species.

In samples from April through June, *Uca* spp. was combined with *Sesarma* spp. and identified only as Grapsizoea spp. (Blanchet, 1976b). Most of these larvae are probably *Uca*, as the stage II larvae are generally more abundant than stage I through most of this period, an anomaly caused by the size of these stages in *Uca*.

Larvae of *Uca* spp. were only occasionally found from November to March, but were common through the rest of the year. The early larvae of this genus are so small that many of the stage I and perhaps some of the stage II zoea are not captured by the 363 μ mesh net used for sampling, leading to underestimation of the abundance of these stages. Stage II *Uca* spp. were nearly always more abundant than stage I when this genus was identified. The larvae of *Sesarma* spp. are somewhat larger, and stage I outnumbered stage II through the part of the year when the genus was separated from *Uca*. The larvae of *Uca* were more common than *Sesarma* through this part of the study period. Considering this, and the *Uca*-like abundance of stage II zoea in the April-June samples, it seems reasonable to assume that *Uca* was also the dominant form in these samples.

Grapsizoea were most abundant in late April and in May samples. Late stage *Uca* (stages IV, V, and megalops) were abundant in late July and all stages of *Uca* peaked in late August, followed by a general decline until November.

Sesarma cinereum were most abundant in July and August samples, while numbers of individuals of *S. reticulatum* were highest in September. Maximum average abundance of both forms of *Sesarma* was only around 2 per m^3. Except for a few first stage zoea of each species recorded on November 22, no *Sesarma* were found from the last of October through March.

Portunid crab larvae were rare in all samples. A few *Callinectes* zoea were recorded from April to September. An unknown portunid zoea (Portunidae sp. A) was recorded in a few samples from April through December. The few portunid megalops found were too damaged to identify to genus. They were recorded in July and November.

Miscellaneous Forms

Very little analysis was done on the meroplankton other than the decapod larvae. The abundance of most of these other forms is grossly underestimated by the mesh size of the net used for this study. As previously mentioned, 75 μ mesh net samples were taken along with the 363 μ mesh samples. Most of these samples were not analyzed quantitatively (due to the limited scope of this study), but the abundance of meroplankton has been reported for one date, January 6, 1976 (Blanchet, 1976a). These abundance figures are similar to those presented by Hopkins (1966), and they place the true abundance of these non-decapod larvae far above the figures for the same forms from the large mesh net. Comparison of the fine mesh net values for January, 1976 with the coarse mesh net values for January, 1977 shows a difference of some 2 to 4 orders of magnitude for such forms as barnacle nauplii and gastropod and bivalve veligers. Without considering the values from the fine mesh net, both gastropod veligers and barnacle nauplii accounted for a significant portion of the meroplankton (3.0% and 1.7% of the total respectively, and 5th and 8th most abundant forms). Were their true abundance known, these forms would probably be the most dominant meroplankton by far.

Though very abundant, many of these larvae come from adult forms whose reproductive potential is much higher than decapod crustaceans and the results of losses due to entrainment may not be as significant to the adult population.

The larvae of oyster (<u>Crassostrea</u> <u>virginica</u>) were recognized in many of the samples from the warmer months. Though some of the gastropod veligers were probably of species predatory on oyster, or otherwise important, no attempt was made to identify them. Without quantitative samples, any study of these forms would have to be very superficial and prone to error.

Entrainment

Entrainment of meroplankton was calculated using the formulas and method outlined in the ichthyoplankton section (Chapter 5) of this report. The estimated monthly entrainment figure for each species by both the dilution pump and the plant between January, 1976 - March, 1977 is listed in Appendices 6C-1 through 6C-15. The entrainment figures for certain crab species, which may be impinged upon the intake screens (for example <u>Polyonyx</u> <u>gibbesi</u>) and for certain small species, which pass through the 363 μ mesh unit (for example molluscan veligers) may be low estimates.

Discussion of entrainment will include the four most abundant species collected in the study area. These are, in order of abundance: _Pinnixa sayana_ (Pinnotheridae); _Polyonyx gibbesi_ (Porcellanidae); _Upogebia affinis_ (Callianassidae); _Neopanope texana_ (Xanthidae). A species of commercial importance, the stone crab (_Menippe mercenaria_) will also be discussed. In addition, total meroplankton entrainment will also be briefly discussed.

1) _Pinnixa sayana_

The estimated monthly entrainment of _P. sayana_ by the dilution pumps and by the plant is presented for the period January, 1976 - March, 1977 in Table 6.1. This species was the most abundant species collected in the area, and was also the most abundant species entrained by the plant and dilution pump. Entrainment was high throughout much of 1976, from March through November. A total of 2.349×10^{11} individuals were entrained by the plant and 8.021×10^{10} individuals were entrained by the dilution pump during 1976.

2) _Polyonyx gibbesi_

The estimated monthly entrainment of _P. gibbesi_ by the dilution pumps and by the plant from January, 1976 - March, 1977 is presented in Table 6.2. This species was both the second most abundant species in the study area and subject to the second highest entrainment of any species. Entrainment of this species

Table 6.1. Estimated number of *Pinnixa sayana* entrained by the Big Bend plant and by the dilution pumps per month between January 1976 and March 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	5.516×10^{7}	0	5.516×10^{7}
March	4.660×10^{9}	1.453×10^{10}	1.919×10^{10}
April	3.728×10^{10}	2.661×10^{10}	6.389×10^{10}
May	1.701×10^{10}	1.504×10^{10}	3.205×10^{10}
June	1.048×10^{10}	3.330×10^{9}	1.381×10^{10}
July	2.623×10^{10}	7.171×10^{9}	3.340×10^{10}
August	1.689×10^{10}	2.138×10^{9}	1.903×10^{10}
September	3.945×10^{10}	2.677×10^{9}	4.213×10^{10}
October	8.028×10^{10}	7.078×10^{9}	8.736×10^{10}
November	2.475×10^{9}	1.629×10^{9}	4.104×10^{9}
December	7.566×10^{7}	7.830×10^{6}	8.349×10^{7}
TOTAL	2.349×10^{11}	8.021×10^{10}	3.151×10^{11}
1977			
January	0	0	0
February	4.533×10^{9}	1.850×10^{9}	6.383×10^{9}
March	6.387×10^{9}	2.606×10^{9}	8.993×10^{9}

Table 6.2. Estimated number of *Polyonyx gibbesi* entrained by the Big Bend plant and by the dilution pumps per month between January 1976 and March 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	1.841×10^{6}	0	1.841×10^{6}
February	1.024×10^{7}	0	1.024×10^{7}
March	1.770×10^{9}	2.551×10^{10}	2.728×10^{10}
April	1.076×10^{10}	4.646×10^{10}	5.722×10^{10}
May	4.765×10^{10}	2.105×10^{10}	6.870×10^{10}
June	5.653×10^{9}	3.757×10^{9}	9.410×10^{9}
July	3.724×10^{9}	1.117×10^{9}	4.841×10^{9}
August	8.849×10^{8}	2.138×10^{8}	1.099×10^{9}
September	2.208×10^{10}	4.134×10^{8}	2.249×10^{10}
October	1.026×10^{10}	6.877×10^{8}	1.095×10^{10}
November	6.640×10^{9}	1.686×10^{8}	6.809×10^{9}
December	1.071×10^{7}	5.860×10^{6}	1.657×10^{7}
TOTAL	1.094×10^{11}	9.938×10^{10}	2.088×10^{11}
1977			
January	0	1.446×10^{6}	1.446×10^{6}
February	0	4.900×10^{5}	4.900×10^{5}
March	0	2.961×10^{5}	2.961×10^{5}

follows a similar monthly pattern to that of _Pinnixa sayana_. Entrainment is high from March through November, 1976. A total of 1.09×10^{11} individuals were entrained by the plant and 9.938×10^{10} individuals by the dilution pump during 1976.

3) _Upogebia affinis_

The estimated monthly entrainment of _U. affinis_ by the dilution pump and by the plant for the period of January, 1976 - March, 1977 is presented in Table 6.3. The third most abundant species collected in the study area, this species also had the third highest entrainment figure. Entrainment was high for this species from March - October, 1976. A total of 4.464×10^{10} individuals were entrained by the plant, and a total of 2.341×10^{10} individuals were entrained by the dilution pump during 1976.

4) _Neopanope texana_

The estimated monthly entrainment of _N. texana_ by the dilution pump and by the plant for the period of January, 1976 - March, 1977 is presented in Table 6.4. The fourth most abundant species collected in the study area, this species also had the fourth highest entrainment figure. Entrainment was highest from August - October, 1976. A total of 4.191×10^{10} individuals were entrained by the plant and 8.087×10^{9} individuals were entrained by the dilution pump during 1976.

5) _Menippe mercenaria_

The estimated number of _M. mercenaria_ entrained monthly by the dilution pump and by the plant from January, 1976 to March,

Table 6.3. Estimated number of *Upogebia affinis* entrained by the Big Bend plant and by the dilution pumps per month between January 1976 and March 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	0	0	0
March	7.748×10^8	3.951×10^9	4.726×10^9
April	1.082×10^{10}	7.365×10^9	1.819×10^{10}
May	1.220×10^{10}	6.750×10^9	1.895×10^{10}
June	3.296×10^9	1.501×10^9	4.797×10^9
July	2.167×10^9	1.498×10^9	3.665×10^9
August	6.889×10^9	7.896×10^8	7.679×10^9
September	7.352×10^9	1.160×10^9	8.512×10^9
October	1.095×10^9	3.494×10^8	1.444×10^9
November	3.455×10^7	3.669×10^7	7.124×10^7
December	8.939×10^6	5.140×10^6	1.408×10^7
TOTAL	4.464×10^{10}	2.341×10^{10}	6.805×10^{10}
1977			
January	0	2.892×10^5	2.892×10^5
February	2.963×10^7	3.523×10^6	3.315×10^7
March	4.174×10^7	4.885×10^6	4.663×10^7

Table 6.4. Estimated number of *Neopanope texana* entrained by the Big Bend plant and by the dilution pumps per month between January 1976 and March 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	0	0	0
March	1.668×10^8	3.736×10^8	5.404×10^8
April	9.108×10^8	6.851×10^8	1.596×10^9
May	6.235×10^8	4.061×10^8	1.030×10^9
June	1.381×10^9	2.958×10^8	1.677×10^9
July	9.172×10^8	4.686×10^8	1.386×10^9
August	1.221×10^{10}	1.138×10^9	1.335×10^{10}
September	1.294×10^{10}	2.686×10^9	1.563×10^{10}
October	1.147×10^{10}	1.409×10^9	1.288×10^{10}
November	1.037×10^9	5.215×10^8	1.558×10^9
December	2.534×10^8	1.035×10^8	3.569×10^8
TOTAL	4.191×10^{10}	8.087×10^9	5.000×10^{10}
1977			
January	2.728×10^6	1.879×10^6	4.607×10^6
February	8.786×10^7	3.335×10^7	1.212×10^8
March	1.231×10^8	4.648×10^7	1.696×10^8

1977 is presented in Table 6.5. Entrainment of this species was highest in August and September, 1976. A total of 5.023×10^9 individuals were entrained by the plant and 1.989×10^9 individuals by the dilution pump during 1976.

6) Total Meroplankton

The estimated number of total meroplankton entrained each month by the dilution pump and the plant is presented in Table 6.6. Entrainment was highest from April through October, 1976. A total of 5.5413×10^{11} individuals were entrained by the dilution pump and 2.496×10^{11} individuals by the plant during 1976, for a total of 7.809×10^{11} individuals entrained.

Since a variety of developmental stages were entrained for a given species in a given month, it was not possible to assess the impact of the entrainment of meroplankton species due to the operation of the power plant without a knowledge of the survival rates between stages.

Table 6.5. Estimated number of *Menippe mercenaria* entrained by the Big Bend plant and by the dilution pumps per month between January 1976 and March 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	0	0	0
March	6.453×10^7	1.779×10^8	2.424×10^8
April	5.642×10^8	3.237×10^8	8.879×10^8
May	2.782×10^8	1.416×10^8	4.198×10^8
June	3.485×10^9	1.748×10^8	5.233×10^8
July	5.306×10^8	3.579×10^8	8.885×10^8
August	1.025×10^9	2.105×10^8	1.235×10^9
September	1.742×10^9	4.965×10^8	2.238×10^9
October	4.529×10^8	9.596×10^7	5.489×10^8
November	1.585×10^7	9.525×10^6	2.538×10^7
December	9.729×10^5	1.059×10^6	2.032×10^6
TOTAL	5.023×10^9	1.989×10^9	7.012×10^9
1977			
January	0	0	0
February	0	0	0
March	0	0	0

Table 6.6. Estimated number of Total meroplankton entrained by the Big Bend plant and by the dilution pumps per month between January 1976 and March 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	5.014×10^{7}	8.178×10^{6}	5.832×10^{7}
February	1.119×10^{9}	0	1.119×10^{9}
March	9.379×10^{9}	4.843×10^{10}	5.781×10^{10}
April	7.191×10^{10}	8.859×10^{10}	1.605×10^{11}
May	8.461×10^{10}	4.800×10^{10}	1.326×10^{11}
June	2.346×10^{10}	1.066×10^{10}	3.412×10^{10}
July	4.129×10^{10}	1.410×10^{10}	5.539×10^{10}
August	5.286×10^{10}	8.514×10^{9}	6.137×10^{10}
September	1.081×10^{11}	1.277×10^{10}	1.209×10^{11}
October	1.177×10^{11}	1.258×10^{10}	1.304×10^{11}
November	2.196×10^{10}	4.629×10^{9}	2.660×10^{10}
December	8.873×10^{9}	1.337×10^{9}	1.021×10^{10}
TOTAL	5.413×10^{11}	2.496×10^{11}	7.909×10^{11}
1977			
January	2.652×10^{9}	1.237×10^{9}	3.889×10^{9}
February	8.759×10^{9}	4.110×10^{9}	1.287×10^{10}
March	1.162×10^{10}	5.453×10^{9}	1.707×10^{10}

SUMMARY AND CONCLUSIONS

1. The decapod crustaceans of the Big Bend area showed major spawning peaks through the warmer months of the year. This pattern is similar to that found in other studies along the northwest coast of Florida. Some depression of breeding occurs during the hottest part of the summer.

2. Most of the decapod larvae found in the study area are non-commercial species whose adults are also residents of the area. The stone crab, Menippe mercenaria, was common, and though a minor fraction of the larvae, 7.012×10^9 zoea of this species were entrained in 1976.

3. Estimates of invertebrate larvae other than decapod larvae were not realistic as the mesh size of the net used in this study allowed many of these larvae to escape.

4. It is not possible to quantify the impact of entrainment of the larvae of any species on the adult population in the area with the data available. Lack of published information on the life histories of the meroplankton species collected at Big Bend and the absence of studies of the mechanisms by which their populations are maintained (i.e. compensatory mechanisms of the species, reproductive potential and strategies, etc.) were the primary reasons for not being able to assess the significance of the entrainment estimates. Also, absence of detailed current

studies in the study area makes the estimations of the areal extent of the sub-populations (which might be affected by the entrainment of their larvae) difficult.

LITERATURE CITED

Avery, W. M., J. R. Leverone and R. H. Blanchet. 1977. Meroplankton, Chapter VI In Tampa Electric Company's 30th Quarterly report on the Big Bend thermal and ecological surveys. Contains twenty-seventh Quarterly Report by Conservation Consultants, Inc. R. Garrity ed.

Blanchet, R. H. 1976a. Meroplankton, Chapter VI p. 318-337 In Tampa Electric Company, 26th Quarterly Report on the Big Bend thermal and ecological surveys. Contains twenty-third Quarterly Report by Conservation Consultants, Inc. R. Garrity ed. 449 p.

Blanchet, R. H. 1976b. Meroplankton, Chapter VI. In Tampa Electric Company, 27th Quarterly Report on the Big Bend thermal and ecological surveys. Contains twenty-fourth Quarterly Report by Conservation Consultants, Inc. R. Garrity ed. 440 p.

Blanchet, R. H. 1976c. Meroplankton, Chapter VI p. 70-77 In Ecological Studies at Beacon Key Tampa Bay, Florida. 23rd Quarterly Report to Tampa Electric Company by Conservation Consultants, Inc. R. Garrity ed. 92 p.

Blanchet, R. H. 1977a. Meroplankton, Chapter VI p. 480-490 In Tampa Electric Company, 28th Quarterly Report on the Big Bend thermal and ecological surveys. Contains Twenty-fifth Quarterly Report by Conservation Consultants, Inc. R. Garrity ed. 651 p.

Blanchet, R. H. 1977b. Meroplankton, Chapter VI p. 451-496 In Tampa Electric Company, 29th Quarterly Report on the Big Bend thermal and ecological surveys. Contains Twenty-sixth Quarterly Report by Conservation Consultants, Inc. R. Garrity ed. 666 p.

Cairns, John Jr., Alan G. Heath, and Bruce C. Parker. 1975. The effects of temperature upon the toxicity of chemicals to aquatic organisms. Hydrobiologia 47(1):135-171.

Chace, Fenner A. Jr. 1972. The Shrimps of the Smithsonian - Bredin Carribean Expeditions with a Summary of the West Indian Shallow-water Species (Crustacea: Decapoda: Natantia). Smithsonian Contributions to Zoology, 98:179 p.

Clark, J. and W. Brownell. 1973. Electric power plants in the coastal zone: environmental issues. Amer. Littoral Soc. Spec. Publ. No. 7. 125 p.

Costlow, J. D., Jr. and C. G. Bookhout. 1962. The effect of environmental factors on larval development of crabs. Biol. Probl. in Water Pollut. 3rd Seminar. 77-86.

Costlow, J. D., Jr., and C. G. Bookhout. 1971. The effect of cyclic temperatures on larval development in the mud-crab _Rithropanopeus harvisii_. p. 211-220 _In_ D. J. Crisp (ed.). Fourth European Marine Biology Symposium. Cambridge University Press.

Costlow, J. D., Jr., C. G. Bookhout, and R. J. Monroe. 1966. Studies on the larval development of the crab, _Rithropanopeus harvisii_ (Gould). I. The effect of salinity and temperature on larval development. Physiol. Zool. 39:81-100.

Fogeringham, N. and R. A. Bagnall. 1976. Seasonal variation in the occurrence of planktonic larvae of sympatric hermit crabs. J. Exp. Mar. Biol. Ecol. 21:279-287.

Gurney, R. and M. V. LeBour. 1939. The larvae of the decapod genus _Naushonia_ Ann. Mag. Nat. Hist. 11(3):609-614.

Hopkins, T. L. 1966. The plankton of the St. Andrew Bay System, Florida. Publ. Inst. Mar. Sci. Univ. Texas 11:12-64.

Kelly, J. A., Jr. and A. Dragovich. 1967. Occurrence of macrozooplankton in Tampa Bay, Florida, and the adjacent Gulf of Mexico. U.S. Fish and Wildl. Serv. Fish. Bull. 66(2):209-221.

Lauer, G. J., W. T. Waller, G. R. Lanza. 1975. Interfaces of steam electric power plants with aquatic ecosystems. Envir. Letters 9(4):405-430.

Lyons, W. G., S. P. Cobb, D. K. Camp, J. A. Mountain, T. Savage, L. Lyons, and E. A. Joyce, Jr. 1971. Preliminary inventory of marine invertebrates collected near the electrical generating plant, Crystal River, Florida in 1969. Florida Dept. of Natural Resources Marine Research Laboratory, Professional Papers Series No. 14, 45 p.

Rouse, Wesley L. 1969. Littoral crustacea from southwest Florida. Quart. Jour. Florida Acad. Sci. 32(2): 127-152.

Sandifer, P. A. 1972. Larval stages of the shrimp Ogyrides limicola Williams 1955 (Decapoda, Caridea) obtained in the laboratory. Crustaceana 26(1):37-60.

Sandifer, P. A. 1973. Distribution and abundance of decapod crustacean larvae in the York River esturay and adjacent lower Chesapeake Bay, Virginia, 1968-1969. Ches. Sci. 14(4):235-257.

Sandifer, P. A. 1975. The role of pelagic larvae in recruitment to populations of adult decapod crustaceans in the York River estuary and adjacent lower Chesapeake Bay. Estuarine and Coastal Mar. Sci. 3:269-279.

Tabb, D. C. and R. B. Manning. 1961. A checklist of the flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected during the period July, 1957 through September, 1960. Bull. Mar. Sci. Gulf and Carib. 11(4):552-649.

Tagatz, M. E. 1968. Biology of the blue crab, Callinectes sapidus Rathbun in the St. Johns River, Florida. U.S. Fish and Wildl. Serv. Fish. Bull. 67:17-33.

TECO. 1975. Addendum to the Prospectus (Oct. 21, 1975).

Thorhaug, A., H. B. Moore, and H. Albertson. 1971. Laboratory thermal tolerances. p. XI-1 to XI-33 In: Bader, R. G. and M. A. Roessler (principal investigators). An ecological study of South Biscayne Bay and Card Sound. Progress Report to U.S. A.E.C. and Fla. Power and Light Co. July, 1971.

Vargo, S. L. and A. N. Sastry. 1977. Acute temperature and low dissolved oxygen tolerances of brachyuran crab (Cancer irrovatus) larva. Mar. Biol. 40:165-171.

Vernberg, F. J. and W. B. Vernberg. 1974. Synergistic effects of temperature and other environmental parameters on orgnaisms. p. 94-99. In: Thermal Ecology. Technical Information Center, Office of Information Services, U.S. Atomic Energy Commission. 670 p.

Wass, Marvin L. 1955. The decapod crustaceans of Alligator Harbor and adjacent inshore areas of northwestern Florida. Quart. Jour. Fla. Acad. Sci. 18(3): 129-176.

Williams, Austin B. 1965. Marine decapod crustaceans of the Carolinas. Fish. Bull. U.S. Fish and Wildl. Serv. 65(1):i-xi, 1-298.

Williams, Austin B. 1971. A ten-year study of meroplankton in North Carolina estuaries: Annual occurrence of come brachyuran developmental stages. Ches. Sci. 12(2):53-61.

APPENDIX 6.A

KEY TO THE LARVAL DECAPODS OF THE LOWER HILLSBOROUGH BAY, TAMPA, FLORIDA

Antennal scale present....................................1

Antennal scale absent.....................................38

1. Uropods present..22

   Uropods absent...2

2. Single medial telson spine present (Fig. 3A)...........3

   Single medial telson spine absent......................7

3. Medial telson spine largest............................4

   Medial telson spine minute........<u>Upogebia affinis</u> (II)

4. Prominent dorsal spine or spines on abdomen............5

   Small dorsal spines on each segment of abdomen

   ....<u>Callianassa</u> sp. D

5. Telson spine arrangement 16-18+1+16-18.................6

   Telson spine arrangement 7-9+1+7-9

   ....<u>Callianassa</u> sp. A (I)

6. Maxillipeds with 13-15 natatory setae

   ....<u>Callianassa</u> sp. C (I)

   Maxillipeds with five natatory setae

   ....<u>Callianassa</u> sp. B (I)

7. Carapace with prominent spines on posterior margin;

   spine four of telson largest...........................65

Carapace margin lacking posterior spines..............8

8. Lateral margin of telson with subterminal notch and associated spine (Fig. 3B)..........................9

Telson with all spines on distal margin (Fig. 3A) ....*Upogebia affinis* (I)

9. Proximal end of antennules separated from each other by at least width of antennule......................10

Proximal end of antennule separated by less than width of antennule.....................................12

10. Dorso-lateral spines present on fourth and fifth abdominal segments (Fig. 3C).........................11

No spines present on fourth abdominal segment........17

11. Telson longer than width; antennules recurve ....*Ambidexter symmetricus* ?

Telson as wide as long; antennules straight ....*Processa* sp. ?

12. Telson spine length equal except inner pair of spines in stage II...............................13

Telson spine length unequal..........................17

13. One ventral carapace spine present posterior to acute pterygostomian region (Fig. 3D) *Ogyrides limicola*

Ventral carapace spine absent........................14

14. Distal margin of telson straight (Fig. 3B)...........15

Distal margin of telson slightly concave..............16

15. Stage I total length 3.5 mm.... Palaemonetes intermedius

Stage I total length 2.6 mm ....Palaemonetes pugio

....or vulgaris

16. Telson width (stage I) 400 μ ....Palaemon floridanus?

Telson width (stage I) 300 μ ....Periclimenes spp.

17. Abdomen with prominent dorsal spine Tozeuma carolinense

Abdomen without prominent dorsal spine...............18

18. Anterio-ventral margin of carapace denticulate.......19

Anterio-ventral margin of carapace smooth............21

19. Telson with three or more lateral spines (Fig 3K)

..............................Leptochela serritorbita

Telson with less than three lateral spines...........20

20. Rostrum triangular at base, becoming acuminate, extending beyond eyes ....Hippolyte spp.

Rostrum reduced and not extending beyond eyes

.....................................Thor floridanus?

21. Eyes taper to point anteriorly; in second stage fifth pair of legs greatly elongated ....Alpheus spp. (5 sp?)

Eyes spherical, fifth pair of legs equal to fourth in length ....Latreutes parvulus

22. Small dorsal spine present on last abdominal segment

.....................................Lucifer faxoni

Small dorsal spine absent on last abdominal segment 23

23. Single medial telson spine present......*Upogebia affinis*

Single medial telson spine absent......................24

24. Carapace with prominent spines on posterior margin....64

Carapace lacking spines on posterior margin...........25

25. Third leg chelate.............Penaeidae (See Cook, 1966)

Third leg simple.....................................26

26. Epigastric spine(s) present..........................27

Epigastric spine(s) absent...........................29

27. Abdomen with prominent dorsal spine *Palaemon floridanus*?

Abdomen lacking dorsal spines........................28

28. Stage VI total length 6.8 mm ... *Palaemonetes intermedius*

Stage VI total length 3.7 mm .... *Palaemonetes pugio*

....or *vulgaris*

29. Carapace with one spine posterior to acute

pterogostomian region (Fig. 3D)........*Ogyrides limicola*

Carapace otherwise...................................30

30. Posterio-ventral margin of carapace with distinct hook;

Stages IV - post-larvae, rostrum compressed laterally

...................................*Latreutes parvulus*

Rostrum otherwise; posterio-ventral margin of carapace

smooth...31

31. Fifth pair of legs extremely elongate ...... *Alpheus* spp.

Fifth pair of legs otherwise.........................32

32. Proximal end of antennules separated from each other by at least width of antennule..........................33

Antennules otherwise..................................34

33. Dorso-lateral spines present on fourth and fifth abdominal segments..........................Processidae

No spines on fourth abdominal segment..................34

34. Prominent dorsal spine on abdomen ... Tozeuma carolinense

Dorsal spine lacking..................................35

35. Posterior margin of telson convex ....Leptochela serritorbita

Telson otherwise......................................36

36. Anterio-ventral margin of carapace denticulate........37

Anterior-ventral margin of carapace smooth ....Periclimenes spp.

37. Rostrum broad at base, becoming acuminate and extending beyond eyes.........................Hippolyte spp.

Rostrum a short triangular process and not extending beyond eyes ....Thor floridanus?

38. Uropods present.......................................64

Uropods absent..39

39. Three spines on posterior margin of carapace ....Lucifer faxoni

Carapace otherwise....................................40

40. Lateral spines present on carapace........................45

Lateral spines absent on carapace........................41

41. Rostrum at least 2X carapace.............................57

Rostrum less than 2X carapace............................42

42. Lateral spines present on telson............*Libina dubia*

Lateral spines absent on telson..........................43

43. Antennae exopodite at least 3/4 rostral length

(Fig. 3E)..44

Antennae exopodite rarely 1/2 rostral length... *Uca* spp.

44. Carapace length .5 mm............*Sesarma reticulatum* (I)

Carapace length .3 mm...............*Sesarma cinereum* (I)

45. Antennae as long or longer than rostrum..................46

Antennae shorter than rostrum............................52

46. Lateral spines present on telson.........................50

Lateral spines absent on telson..........................47

47. Minute dorsal spine present on each furca of telson

(Fig. 3F)..48

Minute dorsal spine absent on furcae.....................49

48. Dorsal spine of carapace with distinct hook

.....................................*Eurypanopeus depressus*

Dorsal spine of carapace straight.......*Neopanope texana*

49. Large spines on fourth abdominal segment

...................................*Rithropanopeus harrisii*

Abdominal spines equal in length

.................................*Hexapanopeus angustifrons*

50. Rostrum shorter than antennae .... Pilimnus spp.

Rostrum otherwise...51

51. Small hair present adjacent and distally to lateral telson spine (Fig. 3G) .... Panopeus herbstii

Telson with single lateral spine .... Portunidae

52. Minute dorsal spine present on each furca of telson ....Unknown Brachyuran A

Minute dorsal spine absent on furcae.................53

53. Dorso-lateral spines present on each segment of abdomen.................................Menippe mercenaria

Dorso-lateral spines absent on abdomen...............54

54. Fifth abdominal segment compressed laterally into lappets (Fig. 3H).......................................55

Fifth abdominal segment otherwise......................56

55. Telson with median deltoid process (Fig. 3H) ....Pinnixa chaetopterana

Telson without median deltoid process .... Pinnixa sayana

56. Telson bifurcate..57

Telson broad with 5-6 spines medially ....Persephone punctata

57. Carapace spines equal to carapace length ....Pinnotheres maculatus

Carapace spines less than carapace length ....Pinnotheres sp. A

58. Telson spine length as long as telson.................59

Telson with short spines.......................Albuneidae

59. Exopodite of antennae as long as endopodite...........60

Endopodite of antennae longer than exopodite..........62

60. Telson with two short medial spurs (Fig. 3I)..........61

Telson with median free of spurs (Fig. 3J)

......................................<u>Petrolisthes</u> spp.

61. Spines present on posterior margin of carapace

...................................<u>Euceramus</u> <u>praelongus</u>

Posterior margin of carapace bare of spines

....<u>Polyonyx</u> <u>gibbesi</u>

62. Telson with two long medial spines....................63

Telson with single median spine ....<u>Petrolisthes</u> spp.

63. Carapace with spines on posterior margin

...................................<u>Euceramus</u> <u>praelongus</u>

Carapace margin bare of spines <u>Polyonyx</u> <u>gibbesi</u>

64. Small dorsal spine present on last segment of abdomen

....<u>Lucifer</u> <u>faxoni</u>

No dorsal spine present on last segment of abdomen....65

65. Posterior carapace spines pointed ventrally...........66

Posterior carapace spines pointing posteriorly

....Pagurid sp. A

66. Lateral abdominal spines equal in length..............67

Lateral spines of fifth abdominal segment 2X length of others .... Pagurus longicarpus

67. Carapace length .9-1.3 mm .... Pagurus annulipes (1)

Carapace length 1.6 mm .... Pagurus pollicaris (1)

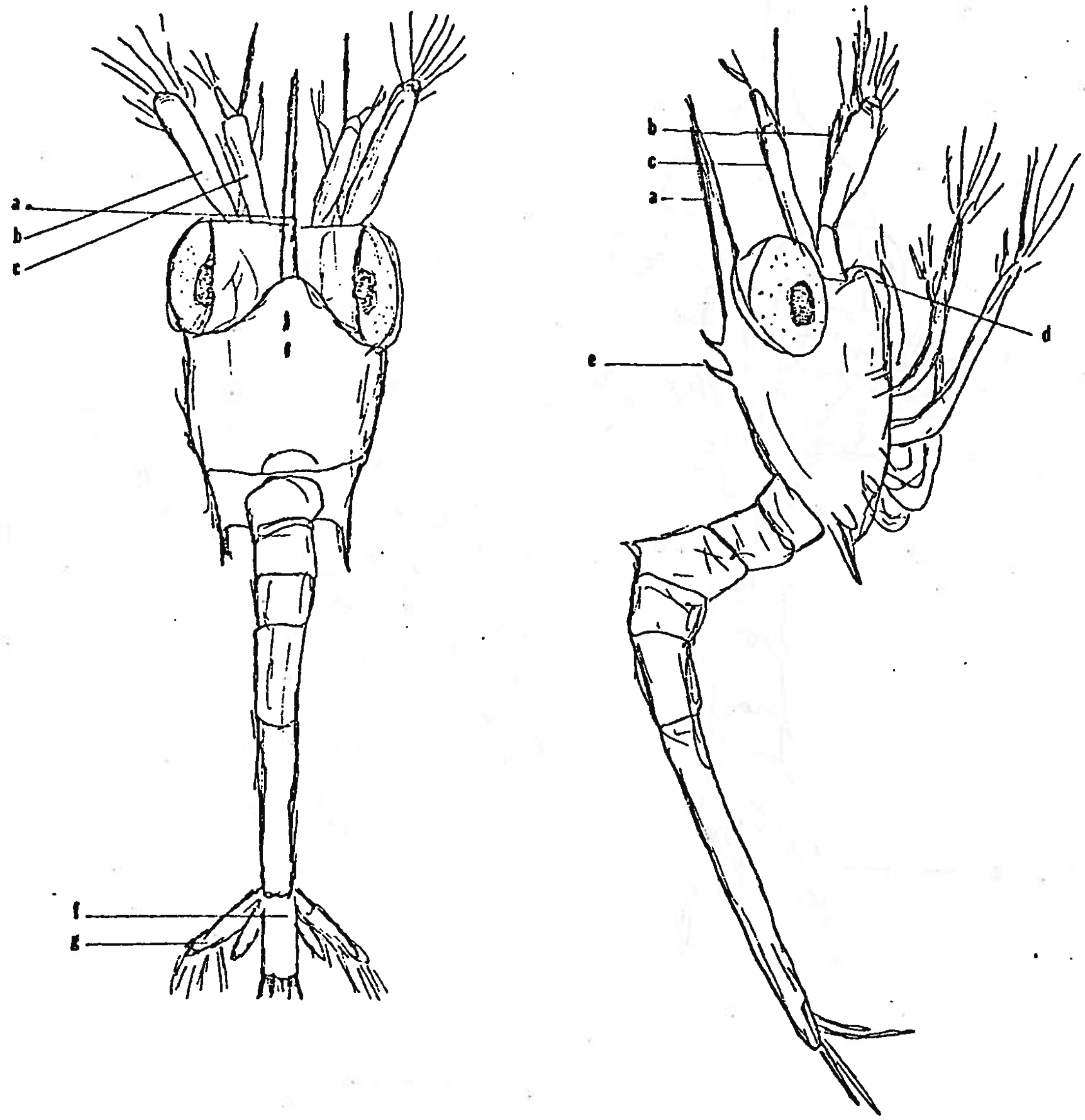


Figure 1.

(Modified after Gurney, 1936)

a. rostrum b. antennal scale c. antennule
d. pterygostimian region e. epigastric spine
f. telson g. uropods

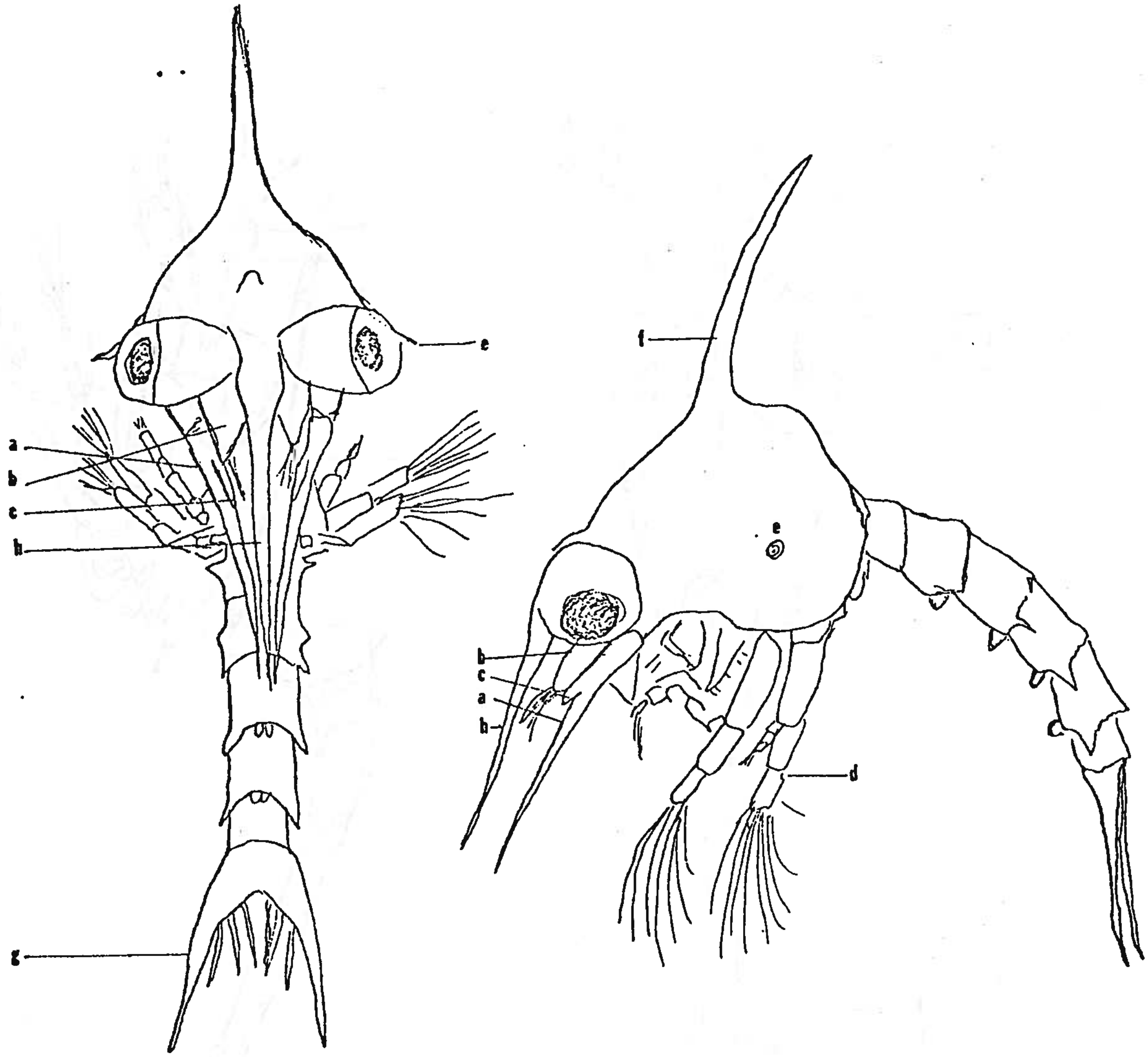


Figure 2.

(After McMahan 1967)

a. antenna b. antennule c. endopodite of antenna
d. maxilliped e. lateral carapace spine
f. dorsal carapace spine g. telson furcae
h. rostrum

Figure 3.

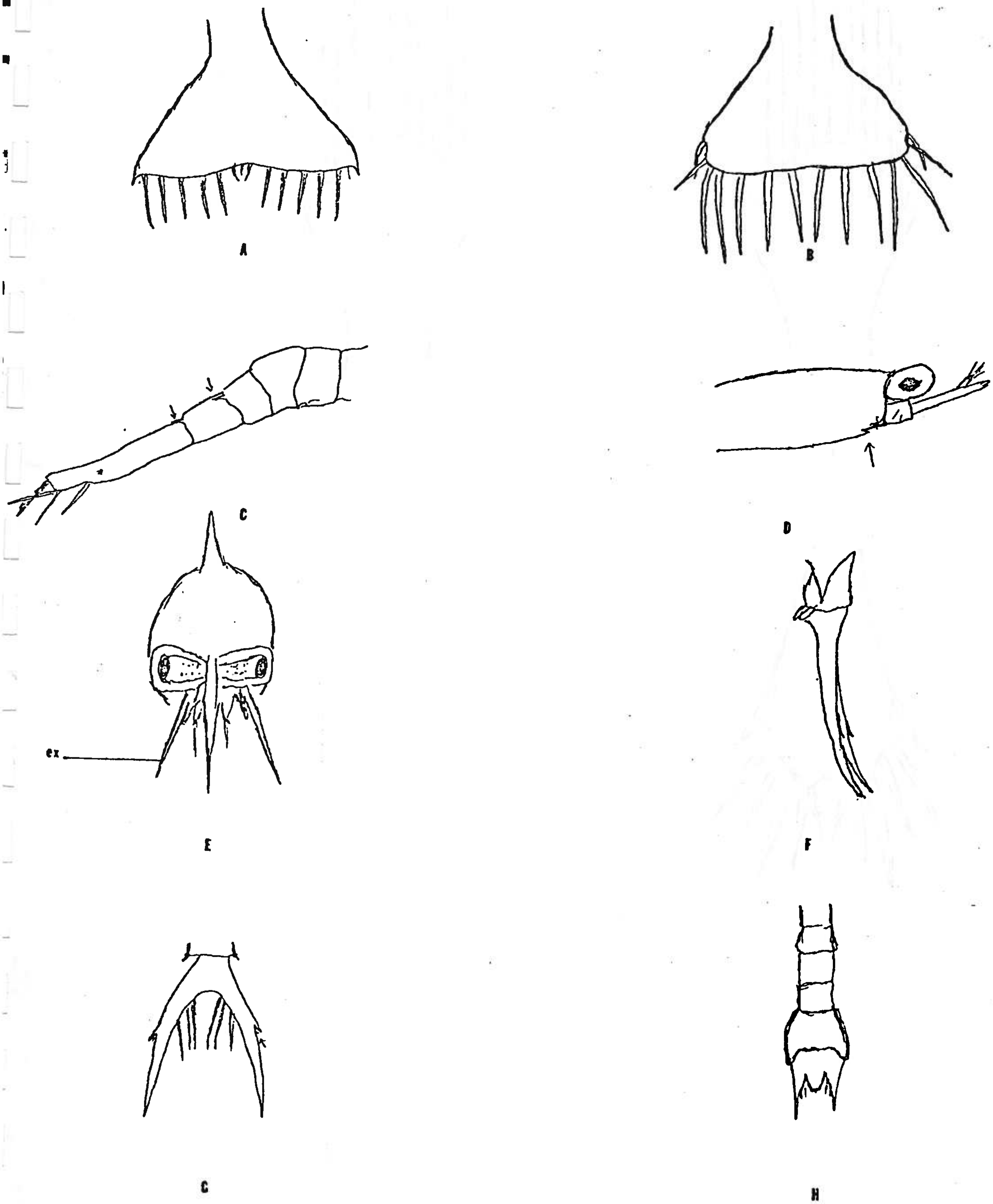
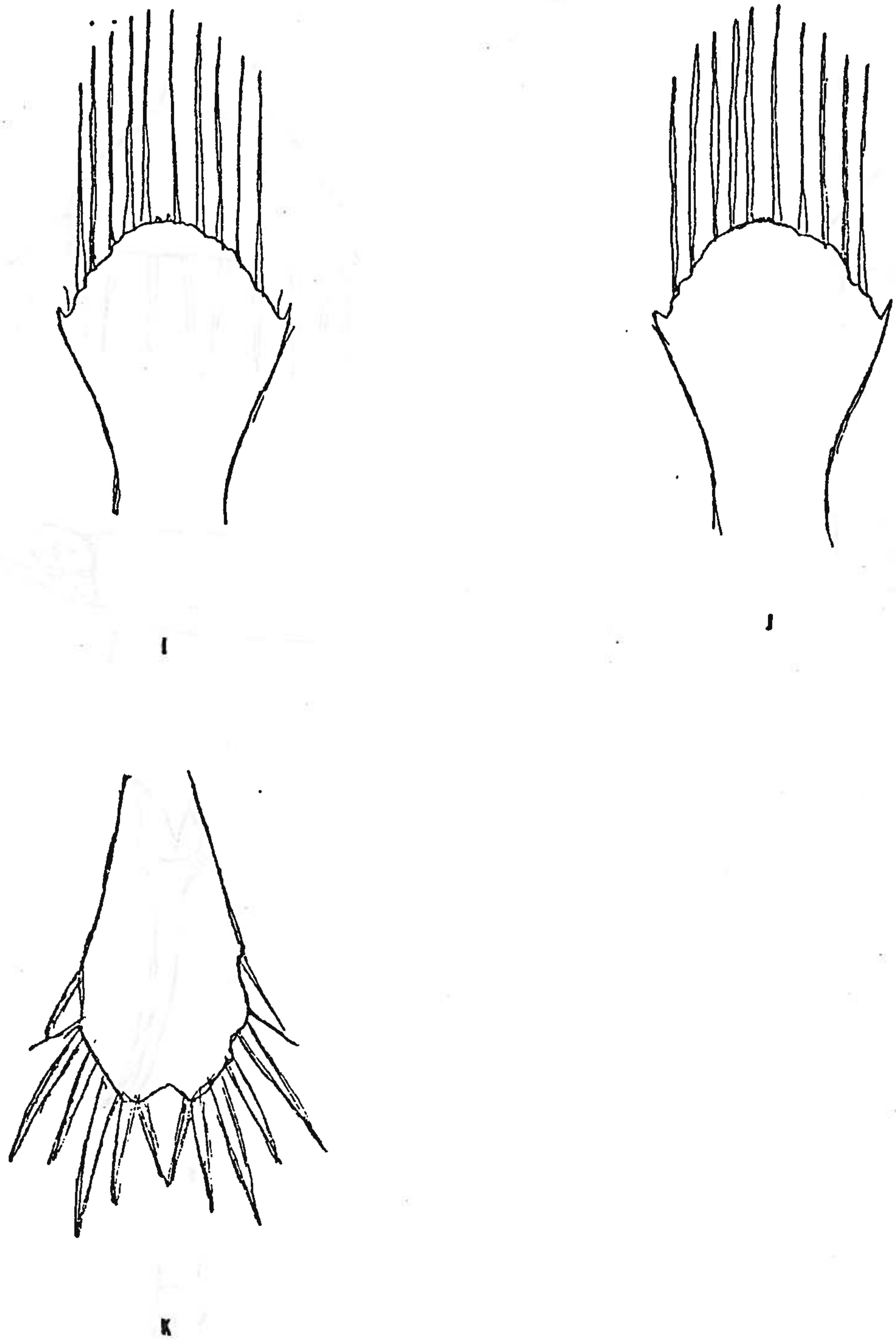


Figure 3.



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BIBLIOGRAPHY

Bookhout, C.G. and J.D. Costlow Jr. 1974. Larval development of *Portunus spinicarpus* reared in the laboratory.

Broad, A.C. 1957. Larval development of *Palaemonetes pugio* Holthuis. Biol. Bull. 112: 141-161.

Chamberlain, N.A. 1957. Larval development of the mud crab *Neopanope texana sayi* (Smith). Biol. Bull. 113:338.

Cook, Harry L. 1965. A generic key to the protozoean, mysis, and postlarval stages of the littoral Penaeidae of the northwestern Gulf of Mexico. Fishery Bulletin: 65 (2): 437-447.

Costlow, J.D., Jr. and C.G. Bookhout, 1959. The larval development of *Callinectes sapidus* Rathbun reared in the laboratory. Biol. Bull. 116: 373-396.

Costlow, J.D., Jr. and C.G. Bookhout, 1960. The complete larval development of *Sesarma cinereum* (Bosc) reared in the laboratory. Biol. Bull. 118 (2): 203-214.

Costlow, J.D., Jr. and C.G. Bookhout, 1961a. The larval development of *Eurypanopeus depressus* (Smith) under laboratory conditions. Crustaceana, 2: 6-15.

Costlow, J.D., Jr. and C.G. Bookhout, 1961b. The larval stages of *Panopeus herbstii* Milne-Edwards reared in the laboratory. Journ. Elisha Mitchell Sci. Soc. 77: 33-42.

Costlow, J.D., Jr. and C.G. Bookhout, 1962. The larval development of *Sesarma reticulatum* Say reared in the laboratory. Crustaceana, 4 (4): 281-294.

Costlow, J.D., Jr. and C.G. Bookhout, 1966a. Larval development of the crab *Hexapanopeus angustifrons* Ches. Sci. 7 (3): 148-156.

Costlow, J.D., Jr. and C.G. Bookhout, 1966b. Larval stages of the crab, *Pinnotheres maculatus*, under laboratory conditions. Ches. Sci. Vol. 7 (3): 157-163.

Costlow, J.D. and C.G. Bookhout, 1971. The effects of cyclic temperatures on larval development in the mud crab Rithropanopeus harrisii. Fourth European Marine Biology Sympsium. p. 211-220.

Ewald, J.J. 1969. Observations on the biology of Tozeuma carolinense (Decapoda, Hippolytidae) from Florida, with special reference to larval development. Bull. Mar. Sci. 19: 510-549.

Gore, R.H. 1968. The larval development of the commensal crab Polyonyx gibbesi Haig, 1956 (Crustacea: Decapoda). Biol. Bull. (Woods Hole) 135: 111-129.

Gore, R.H. 1970. Petrolisthes armatus: a redescription of larval development under laboratory conditions (Decapoda, Porcellanidae). Crustaceana, 18: 75-89.

Hart, J. 1935. The larval development of British Columbia Brachyura. I: Xanthidae, Pinnotheridae and Grapsidae. Canad. J. Res. 12: 411-432.

Hart, J. 1960. The larval development of the British Columbia Brachyura. II. Majidae, subfamily Oregoniinae. Canad. J. Zool. 38: 539-546.

Hood, M. Roy, 1962. Studies on the larval development of Rithropanopeus harrisii (Gould) of the family Xanthidae (Brachyura). Gulf Research Reports, Ocean Springs, Miss. 1 (3): 122-130. 3 pls.

Hubschman, J.H. 1972. The larval development of Palaemonetes intermedius Holthuis, 1949 (Decapoda, Palaemonidae) reared in the laboratory. Crustaceana, 26: 89-103.

Hyman, O.W. 1920. The development of Gelasimus after hatching. Journal of Morphology, 33 (2): 485-501. 12 pls. (genus UCA).

Hyman, O.W. 1924. Studies on larvae of crabs of the family Grapsidae. Proc. U.S. Nat. Mus. 65: art. 10, 1-8.

Hyman, O.W. 1925. Studies on the larvae of crabs of the family Pinnotheridae. Proc. U.S. Nat. Mus. 64: art. 7: 1-9.

Hyman, O.W. 1925. Studies on the larvae of crabs of the family Xanthidae. Proc. U.S. Nat. Mus. 67: art. 3, 1-22.

Lebour, M.V. 1928. Studies of the Plymouth Brachyura. II. The larval stages of Ebalia and Pinnotheres J. Mar. Biol. Ass. U.K. 15: 109-124.

Lebour, M.V. 1932. The larval stages of the Plymouth Caridea IV: The Alpheidae. Proc. Zool. Soc. Lond. 1932: 463-469.

Lebour, M.V. 1941. Notes on thallissinid and processid larvae (Crustacea Decapoda) from Bermuda. Ann. & Mag. of Nat. Hist. ser. 11, Vol. 7, no. 135 pp. 401-420.

Lebour, M.V. 1943. The larvae of the genus Porcellana (Crustacea Decapoda) and its related forms. J. Mar. Biol. Ass. U.K. 25: 721-737.

Lebour, M.V. 1944. Larval crabs from Bermuda. Zoologica, 29 (3): 113-128.

Lebour, M.V. 1950. Notes on some larval decapods (Crustacea) from Bermuda. Proc. Zool. Soc. London,120: 369-379.

McMahan, M.R. 1967. The larval development of Neopanope texana texana (Stimpson) Florida Board of Conservation Leaflet Series: Vol. II - miniature invertebrates Part 1 (1): 1-16.

Nyblade, C. 1970. Larval development of Pagurus annulipes (Stimpson, 1862) and Pagurus pollicanis Say, 1817 reared in the laboratory. Biol. Bull. 139: 557-573.

Porter, H.J. 1960. Zoeal stages of the stone crab, Menippe mercenaria Say. Ches. Sci. 1: 168-177.

Roberts, M.H.,Jr. 1968. Larval development of the decapod Euceramus praelongus in laboratory culture. Ches. Sci. 9: 121-130.

Roberts, M.H., Jr. 1970. Larval development of Pagurus longicarpus Say reared in the laboratory, I. Description of larval instars. Biol. Bull. 139: 338-351.

Sandifer, Paul A. 1972. Larval stages of the shrimp Ogyrides limicola Williams, 1955 (Decapoda, Caridea) obtained in the laboratory. Crustaceana,26 (1): 37-60.

Sandifer, Paul A. 1973a. Larvae of the burrowing shrimp Upogebia affinis, (Crustacea, Decapoda, Upogebiidae) from Virginia plankton. Ches. Sci. Vol. 14 (2): 98-104.

Sandifer, Paul A. 1973b. Mud shrimp (Callianassa) larvae (Crustacea, Decapoda, Callianassidae) from Virginia plankton. Ches. Sci. 14 (3): 149-159.

Williams, A.B. 1965. Marine decapod crustaceans of the Carolinas. Fishery Bull. (65): 1 298 p.

Appendix 6.B. Species list, density and relative abundance for all meroplankton collected at Big Bend area from January 6, 1976 to March 11, 1977.

Species	#/m^3	% Total
Pinnixa sayana	148.41	34.70
Polyonyx gibbesi	120.95	28.28
Upogebia affinis	46.05	10.77
Neopanope texana	18.94	4.43
*Gastropoda	12.69	2.97
Hexapanopeus angustifrons	10.78	2.52
Pinnixa chaetopterana	8.78	2.05
*Balanus sp.	7.26	1.70
Ambidexter symmetricus	5.21	1.22
Xanthidae (damaged)	5.06	1.18
Alpheidae sp. A	4.65	1.09
Periclimenes spp.	4.23	<1.0
Eurypanopeus depressus	3.66	
Grapsizoea spp.	3.15	
Uca spp.	2.83	
Menippe mercenaria	2.31	
Pinnotheres maculatus	2.26	
Persephona punctata	1.94	
*Brachiopoda	1.69	
*Spionidae	1.49	
Ogyrides limicola	1.32	
Echinodermata	1.09	
Pelecypoda	0.93	
Latreutes parvulus	0.925	
Panopeus herbstii	0.838	
Petrolisthes spp.	0.830	
Porcellanidae (damaged)	0.732	

Appendix 6.B. Continued.

Species	#/m³	% Total
Caridea (damaged)	0.678	
Hippolyte spp.	0.615	
Pagurus longicarpus	0.575	
*Nereidae	0.474	
Sesarma cinereum	0.460	
Decapoda (damaged)	0.450	
Paguridae sp. A	0.381	< 0.1
Alpheidae sp. C	0.368	
Sesarma reticulatum	0.362	
Alpheidae (damaged)	0.348	
Processa spp.	0.338	
*Polychaeta	0.305	
Rithropanopeus harrisii	0.262	
Palaemonetes intermedius	0.253	
Pinnotheridae (damaged)	0.247	
Palaemonidae (damaged)	0.228	
Libinia dubia	0.200	
Squilla sp.	0.195	
Palaemonetes spp.	0.151	
Urochordata	0.140	
Brachyura (unidentified)	0.123	
Hippolytidae (damaged)	0.122	
Neopanope packardii	0.103	
Leptochela sp.	0.101	
Alpheidae sp. B	0.098	
Megalops (unidentified)	0.094	
Periclimenes americanus (postlarvae)	0.075	
Palaemonetes pugio/vulgaris	0.059	

Appendix 6.B. Continued.

Species	#/m^3	% Total
Palaemonidae sp. C	0.058	
Portunidae sp. A	0.053	
Alpheidae sp. D	0.048	
Palaemon floridanus	0.047	
Callianassa sp. A	0.046	
Tozeuma carolinense	0.046	
*Polynoidae	0.043	
Pinnixa sp. A	0.043	
Pagurus annulipes	0.039	< 0.01
Pinnotheres sp. A	0.038	
Brachyura sp. A	0.031	
Processidae (damaged)	0.029	
Callinectes sp. A	0.029	
Hippolytidae sp. D	0.029	
Callianassa sp. D	0.025	
Paguridae (damaged)	0.023	
Penaeus duorarum	0.022	
Euceramus praelongus	0.020	
Aegathoa	0.020	
*Phoronida	0.019	
Zoea (unidentified)	0.015	
Callianassa sp. C	0.014	
Paguridae sp. C	0.012	
*Flabelligeridae	0.012	
Pinnotheres sp. B	0.012	
Postlarvae (unidentified)	0.010	
*Syllidae	0.010	
Brachyura sp. B	0.008	
Callianassa sp. B	0.007	

Appendix 6.B. Continued

Species	#/m^3	% Total
Leptochela serritorbita	0.007	
Leucosiidae (damaged)	0.007	
Hippolytidae sp. B	0.006	
*Branchiostoma caribaeum	0.006	
Majidae (damaged)	0.006	
Palaemonidae sp. B	0.005	
Periclimenes longicaudatus (postlarvae)	0.005	
Grapsizoea sp. A	0.005	
*Limulus polyphemus	0.005	
Portunidae (damaged)	0.004	< 0.001
Thor floridanus	0.003	
Grapsidae (damaged)	0.003	
Pinnixa sp. B	0.003	
Hippolytidae sp. A	0.002	
Hippolyte zostericola (postlarvae)	0.002	
*Orbiniidae	0.002	
Alpheidae sp. E	0.002	
Pagurus pollicaris	0.002	
Alpheus sp. (postlarvae)	0.002	
Alpheus heterochaelis (postlarvae)	0.001	
Porcellana sayana	0.001	
Leander sp.	0.001	
Naushonia sp.	0.001	
Penaeidae (damaged)	0.001	
Callianassidae (damaged)	0.001	
*Cirratulidae	0.001	
Callinectes sapidus (postlarvae)	0.001	
TOTAL	427.706	

*Qualitatively sampled

Appendix 6C-1. Estimated Number of Meroplankton Entrained During January, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Decapoda			
Unidentified	2.046×10^5	0	2.046×10^5
Palaemonidae			
Unidentified	2.251×10^6	1.983×10^5	2.251×10^6
Caridea			
Unidentified	4.502×10^6	4.956×10^5	4.998×10^6
Porcellanidae			
Polyonyx gibbesi	1.841×10^6	0	1.841×10^6
Unidentified	2.046×10^5	0	2.046×10^5
Paguridae			
Pagurus annulipes	4.092×10^5	9.913×10^4	5.083×10^5
Pagurus longicarpus	2.762×10^7	5.948×10^6	3.357×10^7
Pagurus pollicaris	4.092×10^5	0	4.092×10^5
Unidentified	4.092×10^5	0	4.092×10^5
Xanthidae			
Unidentified	1.208×10^7	1.437×10^6	1.352×10^7
Isopoda			
Aegathoa sp.	2.046×10^5	0	2.046×10^5
TOTAL	5.014×10^7	8.178×10^6	5.832×10^7

Appendix 6C-2. Estimated Number of Meroplankton Entrained During February, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Decapoda			
Unidentified	2.310×10^4	0	2.310×10^4
Palaemonidae			
Unidentified	5.778×10^5	0	5.778×10^5
Caridea			
Unidentified	2.786×10^7	0	2.786×10^7
Porcellanidae			
Polyoyx gibbesi	1.024×10^7	0	1.024×10^7
Unidentified	4.231×10^6	0	4.231×10^6
Paguridae			
Pagurus annulipes	4.620×10^4	0	4.620×10^4
Pagurus longicarpus	2.561×10^7	0	2.561×10^7
Pagurus pollicaris	4.620×10^4	0	4.620×10^4
Unidentified	4.620×10^4	0	4.620×10^4
Xanthidae			
Unidentified	9.901×10^8	0	9.901×10^8
Pinnotheridae			
Pinnixa sayana	5.516×10^7	0	5.516×10^7
Unidentified	1.618×10^6	0	1.618×10^6
Majidae			
Libinia dubia	1.618×10^6	0	1.618×10^6
Isopoda			
Aegathoa sp.	1.642×10^6	0	1.642×10^6
TOTAL	1.119×10^9	0	1.119×10^9

Appendix 6C-3. Estimated Number of Meroplankton Entrained During March, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Stomatopoda			
Squilla sp.	0	4.156×10^6	4.156×10^6
Decapoda			
Unidentified	4.170×10^7	8.428×10^7	1.260×10^8
Palaemonidae			
Periclimenes spp.	5.932×10^6	1.361×10^8	1.420×10^8
Palaemonetes spp.	5.932×10^6	8.309×10^6	1.424×10^7
Unidentified	2.023×10^7	4.156×10^6	2.439×10^7
Alpheidae			
Unidentified sp. A	2.146×10^8	1.936×10^8	4.082×10^8
Unidentified sp. B	0	7.054×10^7	7.054×10^7
Unidentified sp. C	4.983×10^6	4.156×10^6	9.139×10^6
Unidentified sp. D	1.987×10^7	8.309×10^6	2.818×10^7
Unidentified	2.965×10^6	2.733×10^7	3.029×10^7
Hippolytidae			
Hippolyte spp.	0	8.309×10^6	8.309×10^6
Unidentified sp. B	0	9.507×10^6	9.507×10^6
Unidentified sp. C	0	4.156×10^6	4.156×10^6
Unidentified	0	4.156×10^6	4.156×10^6
Processidae			
Ambidexter symmetricus	2.283×10^7	1.170×10^8	1.398×10^8
Caridea			
Unidentified	2.520×10^7	1.254×10^7	3.774×10^7
Calliannasside			
Upogebia affinis	7.748×10^8	3.951×10^9	4.726×10^9
Unidentified sp. C	4.983×10^6	0	4.983×10^6

Appendix 6C-3. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Porcellanidae			
Petrolisthes spp.	0	4.156×10^6	4.156×10^6
Polyonyx gibbesi	1.770×10^9	2.551×10^{10}	2.728×10^{10}
Unidentified	2.772×10^7	1.247×10^7	4.019×10^7
Paguridae			
Pagurus longicarpus	4.754×10^7	1.635×10^8	2.110×10^8
Unidentified sp. A	0	6.199×10^7	6.199×10^7
Unidentified	0	4.156×10^6	4.156×10^6
Leucosiidae			
Persephone aquilonaris	3.878×10^7	1.426×10^8	1.814×10^8
Portunidae			
Unidentified sp. A	0	4.156×10^6	4.156×10^6
Xanthidae			
Eurypanopeus depressus	1.311×10^8	6.504×10^8	7.815×10^8
Hexapanopeus angustifrons	1.321×10^8	8.428×10^8	9.749×10^8
Menippe mercenaria	6.453×10^7	1.779×10^8	2.424×10^8
Neopanope texana texana	1.668×10^8	3.736×10^8	5.404×10^8
Panopeus herbstii	1.690×10^7	0	1.690×10^7
Unidentified	1.027×10^9	5.192×10^8	1.546×10^9
Pinnotheridae			
Pinnixa chaetopterana	3.777×10^7	3.016×10^8	3.394×10^8
Pinnixa sayana	4.660×10^9	1.453×10^{10}	1.919×10^{10}
Pinnotheres maculatus	5.932×10^6	0	5.932×10^6
Unidentified	1.145×10^7	3.324×10^7	4.469×10^7
Grapsizoea spp.	7.645×10^7	3.987×10^8	4.752×10^8
Majidae			
Libinia dubia	9.439×10^6	0	9.439×10^6

Appendix 6C-3. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Brachyura			
Unidentified	0	4.156×10^6	4.156×10^6
Mollusca			
Gastropoda	4.983×10^6	4.753×10^7	5.252×10^7
Pelecypoda	4.983×10^6	0	4.983×10^6
Isopoda			
Aegathoa sp.	1.492×10^6	0	1.492×10^6
TOTAL	9.379×10^9	4.843×10^{10}	5.781×10^{10}

Appendix 6C-4. Estimated Number of Meroplankton Entrained During April, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Stomatopoda			
Squilla sp.	2.717×10^7	1.097×10^7	3.814×10^7
Decapoda			
Unidentified	1.112×10^8	1.572×10^8	2.684×10^8
Palaemonidae			
Periclimenes spp.	2.138×10^8	2.501×10^8	4.639×10^8
Palaemonetes spp.	1.582×10^7	1.578×10^7	3.160×10^7
Unidentified	8.031×10^7	9.313×10^6	8.962×10^7
Alpheidae			
Alpheus heterochaelis	0	3.818×10^5	3.818×10^5
Unidentified sp. A	1.360×10^9	3.586×10^8	1.719×10^9
Unidentified sp. B	0	1.266×10^8	1.266×10^8
Unidentified sp. C	5.207×10^7	7.404×10^6	5.947×10^7
Unidentified sp. D	5.298×10^7	1.971×10^7	7.269×10^7
Unidentified	4.669×10^7	5.636×10^7	1.030×10^8
Hippolytidae			
Hippolyte spp.	1.049×10^8	1.548×10^7	1.204×10^8
Tozeuma carolinense	2.717×10^7	0	2.717×10^7
Unidentified sp. B	0	1.693×10^7	1.693×10^7
Unidentified sp. C	0	7.785×10^6	7.785×10^6
Unidentified	0	7.627×10^6	7.627×10^6
Processidae			
Ambidexter symmetricus	1.269×10^8	2.135×10^8	3.404×10^8
Caridea			
Unidentified	0	2.672×10^7	2.672×10^7

Appendix 6C-4. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Callianassidae			
Upogebia affinis	1.082×10^{10}	7.365×10^{9}	1.819×10^{10}
Unidentified sp. C	1.329×10^{7}	0	1.329×10^{7}
Porcellanidae			
Petrolisthes spp.	7.772×10^{7}	8.549×10^{6}	8.627×10^{7}
Polyonyx gibbesi	1.076×10^{10}	4.646×10^{10}	5.722×10^{10}
Unidentified	6.358×10^{7}	2.515×10^{7}	8.873×10^{7}
Paguridae			
Pagurus longicarpus	1.764×10^{8}	2.914×10^{8}	4.678×10^{8}
Unidentified sp. A	0	1.109×10^{8}	1.109×10^{8}
Unidentified	0	7.404×10^{6}	7.404×10^{6}
Leucosiidae			
Persephone aquilonaris	5.617×10^{8}	2.589×10^{8}	8.206×10^{8}
Portunidae			
Unidentified sp. A	0	8.383×10^{6}	8.383×10^{6}
Xanthidae			
Eurypanopeus depressus	1.445×10^{9}	1.175×10^{9}	2.620×10^{9}
Hexapanopeus angustifrons	1.374×10^{9}	1.512×10^{9}	2.886×10^{9}
Menippe mercenaria	5.642×10^{8}	3.237×10^{8}	8.879×10^{8}
Neopanope texana texana	9.108×10^{8}	6.851×10^{8}	1.596×10^{9}
Panopeus herbstii	2.974×10^{8}	7.637×10^{5}	2.982×10^{8}
Rithropanopeus harrisii	3.879×10^{7}	3.818×10^{5}	3.917×10^{7}
Unidentified	5.507×10^{8}	9.355×10^{8}	1.486×10^{9}
Pinnotheridae			
Pinnixa chaetopterana	2.326×10^{9}	5.733×10^{8}	2.899×10^{9}
Pinnixa sayana	3.728×10^{10}	2.661×10^{10}	6.389×10^{10}
Pinnotheres maculatus	9.734×10^{7}	2.190×10^{6}	9.953×10^{7}
Unidentified	2.657×10^{7}	5.943×10^{7}	8.600×10^{7}

Appendix 6C-4. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Grapsizoea spp.	1.528×10^9	7.708×10^8	2.299×10^9
Majidae			
Libinia dubia	8.716×10^7	0	8.716×10^7
Brachyura			
Unidentified	2.717×10^7	7.404×10^6	3.457×10^7
Mollusca			
Gastropoda	4.949×10^8	8.717×10^7	5.821×10^8
Pelecypoda	1.687×10^8	1.527×10^6	1.702×10^8
Cirripedia			
Balanus sp.	0	3.047×10^6	3.047×10^6
Polychaeta			
Spionidae	0	6.053×10^5	6.053×10^5
Brachiopoda	0	1.145×10^6	1.145×10^6
Echniodermata			
Ophiuroidea	0	5.453×10^6	5.453×10^6
TOTAL	7.191×10^{10}	8.859×10^{11}	1.605×10^{11}

Appendix 6C-5. Estimated Number of Meroplankton Entrained During May, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Stomatopoda			
Squilla sp.	1.223×10^7	7.369×10^7	8.592×10^7
Decapoda			
Unidentified	5.071×10^7	1.466×10^8	1.973×10^8
Palaemonidae			
Periclimenes spp.	3.108×10^8	1.596×10^8	4.704×10^8
Palaemonetes spp.	1.701×10^7	2.025×10^7	3.726×10^7
Unidentified	1.223×10^7	3.945×10^7	5.168×10^7
Alpheidae			
Alpheus heterochaelis	0	7.890×10^6	7.890×10^6
Unidentified sp. A	4.731×10^8	2.844×10^8	7.575×10^8
Unidentified sp. B	0	2.025×10^7	2.025×10^7
Unidentified sp. C	1.745×10^7	0	1.745×10^7
Unidentified sp. D	0	1.014×10^8	1.014×10^8
Unidentified	2.206×10^8	1.587×10^8	3.793×10^8
Hippolytidae			
Hippolyte spp.	4.720×10^7	1.400×10^7	6.120×10^7
Tozeuma carolineuse	1.223×10^7	0	1.223×10^7
Unidentified sp. C	0	7.890×10^6	7.890×10^6
Unidentified	1.701×10^7	4.615×10^6	2.163×10^7
Processidae			
Ambidexter symmetricus	2.968×10^7	1.064×10^8	1.361×10^8
Unidentified	5.071×10^7	0	5.071×10^7
Caridea			
Unidentified	3.401×10^7	9.051×10^7	1.245×10^8
Callianassidae			
Upogebia affinis	1.220×10^{10}	6.750×10^9	1.895×10^{10}

Appendix 6C-5. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Porcellanidae			
Petrolisthes spp.	1.027×10^8	2.367×10^7	1.264×10^8
Polyonyx gibbesi	4.765×10^{10}	2.105×10^{10}	6.870×10^{10}
Unidentified	0	6.089×10^7	6.089×10^7
Paguridae			
Pagurus longicarpus	4.720×10^7	4.615×10^6	5.182×10^7
Unidentified sp. A	0	9.382×10^6	9.382×10^6
Leucosiidae			
Persephone aquilonaris	3.599×10^8	9.993×10^7	4.598×10^8
Portunidae			
Unidentified sp. A	0	2.025×10^7	2.025×10^7
Xanthidae			
Eurypanopeus depressus	6.128×10^8	3.371×10^8	9.499×10^8
Hexapanopeus angustifrons	6.800×10^8	2.313×10^8	9.113×10^8
Menippe mercenaria	2.782×10^8	1.416×10^8	4.198×10^8
Neopanope texana texana	6.235×10^8	4.061×10^8	1.030×10^9
Panopeus herbstii	1.646×10^8	1.578×10^7	1.804×10^8
Rithropanopeus harrisii	1.745×10^7	7.890×10^6	2.534×10^7
Unidentified	2.299×10^8	2.212×10^8	4.511×10^8
Pinnotheridae			
Pinnixa chaetopterana	1.238×10^9	7.451×10^8	1.983×10^9
Pinnixa sayana	1.701×10^{10}	1.504×10^{10}	3.205×10^{10}
Pinnotheres maculatus	7.070×10^7	4.526×10^7	1.160×10^8
Unidentified	8.472×10^7	4.615×10^6	8.934×10^7
Grapsizoea spp.	1.164×10^9	1.251×10^9	2.415×10^9
Majidae			
Libinia dubia	4.669×10^7	0	4.669×10^7

Appendix 6C-5. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Brachyura			
Unidentified	1.223×10^{7}	0	1.223×10^{7}
Mollusca			
Gastropoda	2.507×10^{8}	5.181×10^{7}	3.025×10^{8}
Pelecypoda	6.992×10^{7}	3.156×10^{7}	1.015×10^{8}
Cirripedia			
<u>Balanus</u> sp.	3.968×10^{8}	6.298×10^{7}	4.598×10^{8}
Polychaeta			
Spionidae	0	1.251×10^{7}	1.251×10^{7}
Brachiopoda	0	2.367×10^{7}	2.367×10^{7}
Echinodermata			
Ophiuroidea	0	1.127×10^{8}	1.127×10^{8}
TOTAL	8.461×10^{10}	4.800×10^{10}	1.326×10^{11}

Appendix 6C-6. Estimated Number of Meroplankton Entrained During June, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Stomatopoda			
Squilla sp.	1.014×10^7	7.497×10^6	1.764×10^7
Decapoda			
Unidentified	3.882×10^6	1.938×10^7	2.327×10^7
Palaemonidae			
Periclimenes spp.	2.238×10^7	2.788×10^7	5.026×10^7
Palaemonetes pugio/vulgaris	1.011×10^6	0	1.011×10^6
Palaemonetes spp.	4.677×10^7	6.698×10^6	5.347×10^7
Unidentified sp. A	1.588×10^7	1.851×10^6	1.773×10^7
Unidentified	5.344×10^7	1.801×10^7	7.145×10^7
Alpheidae			
Alpheus heterochaelis	0	4.636×10^5	4.636×10^5
Unidentified sp. A	9.852×10^7	5.773×10^7	1.562×10^8
Unidentified sp. B	1.596×10^7	1.190×10^6	1.715×10^7
Unidentified sp. C	1.096×10^7	4.844×10^6	1.580×10^7
Unidentified sp. D	5.865×10^7	5.957×10^6	6.461×10^7
Unidentified	1.011×10^6	5.951×10^7	6.052×10^7
Hippolytidae			
Hippolyte spp.	5.934×10^7	1.318×10^6	6.066×10^7
Latreutes parvulus	1.121×10^7	1.355×10^6	1.256×10^7
Tozeuma carolineuse	7.288×10^6	0	7.288×10^6
Unidentified sp. C	0	4.636×10^5	4.636×10^5
Unidentified	9.262×10^6	4.337×10^7	5.263×10^7
Processidae			
Ambidexter symmetricus	1.509×10^7	1.298×10^7	2.807×10^7
Processa spp.	0	1.269×10^7	1.269×10^7
Unidentified	2.870×10^6	4.853×10^7	5.140×10^7

Appendix 6C-6. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Caridea			
Unidentified	1.992×10^7	1.077×10^7	3.069×10^7
Callianassidae			
<u>Upogebia affinis</u>	3.296×10^9	1.501×10^9	4.797×10^9
Unidentified sp. B	0	2.754×10^6	2.754×10^6
Unidentified sp. C	0	1.006×10^7	1.006×10^7
Unidentified sp. D	0	4.354×10^4	4.354×10^4
Porcellanidae			
<u>Petrolisthes</u> spp.	5.635×10^7	4.847×10^7	1.048×10^8
<u>Polyonyx gibbesi</u>	5.653×10^9	3.757×10^9	9.410×10^9
Unidentified	0	4.190×10^7	4.190×10^7
Paguridae			
<u>Pagurus annulipes</u>	1.842×10^6	6.096×10^5	2.452×10^6
<u>Pagurus longicarpus</u>	0	3.743×10^6	3.743×10^6
Unidentified sp. A	7.982×10^6	7.404×10^6	1.539×10^7
Unidentified	0	2.171×10^6	2.171×10^6
Leucosiidae			
<u>Persephone aquilonaris</u>	6.779×10^7	4.553×10^7	1.133×10^8
Portunidae			
Unidentified sp. A	0	1.233×10^6	1.233×10^6
Unidentified	0	3.353×10^6	3.353×10^6
Xanthidae			
<u>Eurypanopeus depressus</u>	2.154×10^8	6.954×10^7	2.849×10^8
<u>Hexapanopeus angustifrons</u>	5.075×10^8	2.675×10^8	7.750×10^8
<u>Menippe mercenaria</u>	3.485×10^8	1.748×10^8	5.233×10^8
<u>Neopanope texana texana</u>	1.381×10^9	2.958×10^8	1.677×10^9
<u>Panopeus herbstii</u>	4.813×10^7	2.094×10^7	6.907×10^7

Appendix 6C-6. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Rithropanopeus harrisii	7.288×10^6	4.636×10^5	7.752×10^6
Unidentified	1.758×10^8	1.385×10^8	3.143×10^8
Pinnotheridae			
Pinnixa chaetopterana	1.329×10^8	1.811×10^8	3.140×10^8
Pinnixa sayana	1.048×10^{10}	3.330×10^9	1.381×10^{10}
Pinnotheres maculatus	1.513×10^7	1.901×10^7	3.414×10^7
Unidentified	1.310×10^7	4.235×10^5	1.352×10^7
Grapsidae			
Sesarma cinereum	2.038×10^6	3.543×10^6	5.581×10^6
Sesarma reticulatum	2.854×10^6	2.466×10^6	5.320×10^6
Ocypodidae			
Uca spp.	2.283×10^7	1.454×10^7	3.737×10^7
Grapsizoea spp.	1.518×10^8	2.474×10^8	3.992×10^8
Majidae			
Libinia dubia	1.623×10^7	4.262×10^6	2.049×10^7
Brachyrua			
Unidentified sp. A	1.842×10^6	0	1.842×10^6
Mollusca			
Gastropoda	1.049×10^8	1.560×10^7	1.205×10^8
Pelecypoda	8.993×10^6	4.146×10^6	1.314×10^7
Isopoda			
Aegathoa sp.	0	3.516×10^6	3.516×10^6
Cirripedia			
Balanus sp.	2.246×10^7	2.826×10^7	5.072×10^7
Polychaeta			
Nereidae	0	1.128×10^7	1.128×10^7

Appendix 6C-6. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Spionidae	1.024×10^{8}	2.448×10^{7}	1.269×10^{8}
Unidentified	2.367×10^{7}	0	2.367×10^{7}
Brachiopoda	1.190×10^{8}	2.375×10^{7}	1.428×10^{8}
Echinodermata			
Ophiuroidea	0	6.621×10^{6}	6.621×10^{6}
Unidentified	0	5.714×10^{5}	5.714×10^{5}
TOTAL	2.346×10^{10}	1.066×10^{10}	3.412×10^{10}

Appendix 6C-7. Estimated Number of Meroplankton Entrained During July, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Stomatopoda			
Squilla sp.	3.710×10^{7}	7.459×10^{6}	4.456×10^{7}
Decapoda			
Unidentified	2.902×10^{7}	8.398×10^{7}	1.130×10^{8}
Penaeidae			
Penaeus duorarum	0	7.347×10^{5}	7.347×10^{5}
Unidentified	1.026×10^{6}	0	1.026×10^{6}
Pasiphaeidae			
Leptochela spp.	3.762×10^{6}	0	3.762×10^{6}
Palaemonidae			
Periclimenes americanus	1.026×10^{6}	0	1.026×10^{6}
Periclimenes spp.	2.863×10^{7}	4.648×10^{6}	3.328×10^{7}
Palaemonetes intermedius	2.066×10^{7}	1.881×10^{7}	3.947×10^{7}
Palaemonetes pugio/ vulgaris	1.708×10^{7}	2.336×10^{7}	4.044×10^{7}
Unidentified sp. A	2.064×10^{8}	2.406×10^{7}	2.305×10^{8}
Unidentified sp. C	0	2.449×10^{5}	2.449×10^{5}
Alpheidae			
Unidentified sp. A	9.924×10^{8}	1.718×10^{8}	1.164×10^{9}
Unidentified sp. B	3.268×10^{6}	0	3.268×10^{6}
Unidentified sp. C	6.487×10^{7}	5.546×10^{7}	1.203×10^{8}
Unidentified	1.315×10^{7}	9.905×10^{6}	2.305×10^{7}
Ogyrididae			
Ogyrides limicola	6.176×10^{6}	2.939×10^{6}	9.115×10^{6}
Hippolytidae			
Hippolyte spp.	0	1.511×10^{7}	1.511×10^{7}
Latreutes parvulus	1.643×10^{8}	4.813×10^{7}	2.124×10^{8}
Unidentified	1.315×10^{7}	0	1.315×10^{7}

Appendix 6C-7. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Processidae			
Ambidexter symmetricus	1.198×10^8	1.849×10^8	3.047×10^8
Unidentified	1.882×10^6	5.661×10^5	2.448×10^6
Caridea			
Unidentified	2.649×10^7	2.005×10^7	4.654×10^7
Callianassidae			
Upogebia affinis	2.167×10^9	1.498×10^9	3.665×10^9
Unidentified sp. A	0	7.347×10^5	7.347×10^5
Unidentified sp. C	3.268×10^6	0	3.268×10^6
Unidentified sp. D	1.026×10^6	2.182×10^6	3.208×10^6
Porcellanidae			
Petrolisthes spp.	2.275×10^8	6.374×10^7	2.912×10^8
Polyonyx gibbesi	3.724×10^9	1.117×10^9	4.841×10^9
Paguridae			
Pagurus annulipes	2.395×10^7	7.924×10^6	3.187×10^7
Unidentified sp. A	5.643×10^6	1.125×10^7	1.690×10^7
Unidentified	0	6.439×10^6	6.439×10^6
Leucosiidae			
Persephone aquilonaris	1.068×10^8	3.899×10^7	1.458×10^8
Portunidae			
Unidentified sp. A	0	5.661×10^5	5.661×10^5
Xanthidae			
Eurypanopeus depressus	3.343×10^8	1.506×10^8	4.849×10^8
Hexapanopeus angustifrons	1.146×10^9	3.864×10^8	1.532×10^9
Menippe mercenaria	5.306×10^8	3.579×10^8	8.885×10^8
Neopanope texana texana	9.172×10^8	4.686×10^8	1.386×10^9
Panopeus herbstii	1.248×10^8	4.476×10^7	1.696×10^8
Unidentified	1.318×10^8	3.362×10^8	4.680×10^8

Appendix 6C-7. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Pinnotheridae			
Pinnixa chaetopterana	3.623×10^{8}	1.835×10^{8}	5.458×10^{8}
Pinnixa sayana	2.623×10^{10}	7.171×10^{9}	3.340×10^{10}
Pinnotheres maculatus	8.692×10^{7}	4.273×10^{7}	1.297×10^{8}
Unidentified	1.315×10^{7}	1.697×10^{7}	3.012×10^{7}
Grapsidae			
Sesarma cinereum	6.046×10^{7}	7.925×10^{7}	1.397×10^{8}
Sesarma reticulatum	4.925×10^{7}	5.878×10^{7}	1.080×10^{8}
Ocypodidae			
Uca spp.	4.114×10^{8}	2.996×10^{8}	7.110×10^{8}
Grapsizoea spp.	0	1.451×10^{7}	1.451×10^{7}
Majidae			
Libinia dubia	0	1.245×10^{7}	1.245×10^{7}
Unidentified	1.401×10^{6}	0	1.401×10^{6}
Brachyura			
Unidentified sp. A	2.395×10^{7}	9.798×10^{4}	2.405×10^{7}
Unidentified	0	6.783×10^{6}	6.783×10^{6}
Mollusca			
Gastropoda	3.541×10^{8}	2.376×10^{8}	5.917×10^{8}
Pelecypoda	2.083×10^{8}	3.848×10^{7}	2.468×10^{8}
Isopoda			
Aegathoa sp.	0	1.061×10^{7}	1.061×10^{7}
Cirripedia			
Balanus sp.	2.983×10^{7}	1.540×10^{8}	1.839×10^{8}
Polychaeta			
Nereidae	3.470×10^{8}	1.545×10^{8}	5.015×10^{8}
Polynoidae	0	9.552×10^{5}	9.552×10^{5}
Spionidae	1.788×10^{9}	3.540×10^{8}	2.142×10^{9}
Unidentified	1.587×10^{7}	0	1.587×10^{7}

Appendix 6C-7. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Brachiopoda	1.074×10^8	7.811×10^7	1.855×10^8
Echinodermata			
Unidentified	0	2.220×10^7	2.220×10^7
TOTAL	4.129×10^{10}	1.410×10^{10}	5.539×10^{10}

Appendix 6C-8. Estimated Number of Meroplankton Entrained During August, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Stomatopoda			
Squilla sp.	7.210×10^6	9.821×10^6	1.703×10^7
Decapoda			
Unidentified	0	6.204×10^5	6.204×10^5
Penaeidae			
Unidentified	2.395×10^6	0	2.395×10^6
Pasiphaeidae			
Leptochela spp.	1.449×10^7	1.306×10^6	1.580×10^7
Palaemonidae			
Periclimenes americanus	2.395×10^6	1.347×10^6	3.742×10^6
Periclimenes spp.	3.680×10^8	8.019×10^7	4.482×10^8
Palaemonetes intermedius	1.896×10^8	1.605×10^6	1.912×10^8
Palaemonetes pugio/vulgaris	9.177×10^6	1.065×10^7	1.983×10^7
Unidentified sp. C	2.631×10^6	8.871×10^6	1.150×10^7
Unidentified	0	4.310×10^6	4.310×10^6
Alpheidae			
Unidentified sp. A	7.009×10^8	3.782×10^7	7.387×10^8
Unidentified sp. B	0	2.789×10^6	2.789×10^6
Unidentified sp. C	1.506×10^8	5.536×10^7	2.060×10^8
Unidentified	3.077×10^6	4.310×10^6	7.387×10^6
Ogyrididae			
Ogyrides limicola	2.324×10^8	6.320×10^7	2.956×10^7
Hippolytidae			
Hippolyte spp.	1.549×10^8	1.903×10^7	1.739×10^8
Latreutes parvulus	3.491×10^8	7.262×10^7	4.217×10^8
Unidentified sp. D	0	1.850×10^5	1.850×10^5
Unidentified	3.077×10^6	0	3.077×10^6

Appendix 6C-8. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Processidae			
Ambidexter symmetricus	1.088×10^9	2.137×10^8	1.302×10^9
Processa spp.	5.263×10^6	4.213×10^6	9.476×10^6
Unidentified	4.390×10^6	0	4.390×10^6
Caridea			
Unidentified	2.006×10^8	4.701×10^7	2.476×10^8
Callianassidae			
Upogebia affinis	6.889×10^9	7.896×10^8	7.679×10^9
Unidentified sp. A	0	4.408×10^6	4.408×10^6
Unidentified sp. B	7.210×10^6	0	7.210×10^6
Unidentified sp. D	2.395×10^6	3.896×10^6	6.291×10^6
Porcellanidae			
Petrolisthes spp.	5.230×10^7	6.343×10^6	5.864×10^7
Polyonyx gibbesi	8.849×10^8	2.138×10^8	1.099×10^9
Paguridae			
Pagurus pollicaris	7.210×10^6	0	7.210×10^6
Unidentified sp. A	3.716×10^7	1.012×10^7	4.728×10^7
Unidentified	0	6.204×10^5	6.204×10^5
Leucosiidae			
Persephone aquilonaris	1.395×10^8	3.583×10^7	1.753×10^8
Portunidae			
Callinectes sp. A	0	4.310×10^6	4.310×10^6
Xanthidae			
Eurypanopeus depressus	1.010×10^9	2.276×10^8	1.238×10^9
Hexapanopeus angustifrons	1.598×10^9	3.738×10^8	1.972×10^9
Menippe mercenaria	1.025×10^9	2.105×10^8	1.235×10^9
Neopanope packardi	0	3.090×10^8	3.090×10^8
Neopanope texana texana	1.221×10^{10}	1.138×10^9	1.335×10^{10}

Appendix 6C-8. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Panopeus herbstii	1.956×10^{8}	2.780×10^{7}	2.234×10^{8}
Rithropanopeus harrisii	2.907×10^{7}	9.108×10^{6}	3.818×10^{7}
Unidentified	1.267×10^{9}	1.868×10^{8}	1.454×10^{9}
Pinnotheridae			
Pinnixa chaetopterana	5.064×10^{8}	1.699×10^{8}	6.763×10^{8}
Pinnixa sayana	1.689×10^{10}	2.138×10^{9}	1.903×10^{10}
Pinnotheres maculatus	2.456×10^{8}	7.576×10^{7}	3.214×10^{8}
Unidentified	0	2.155×10^{6}	2.155×10^{6}
Grapsidae			
Sesarma cinereum	3.053×10^{8}	4.452×10^{7}	3.498×10^{8}
Sesarma reticulatum	9.925×10^{7}	2.222×10^{7}	1.215×10^{8}
Ocypodidae			
Uca spp.	2.813×10^{9}	7.570×10^{8}	3.570×10^{9}
Grapsizoea spp.	6.409×10^{7}	2.721×10^{7}	9.130×10^{7}
Majidae			
Libinia dubia	2.970×10^{7}	1.141×10^{7}	4.111×10^{7}
Brachyura			
Unidentified sp. A	0	5.527×10^{6}	5.527×10^{6}
Unidentified	8.551×10^{7}	9.688×10^{6}	9.520×10^{7}
Mollusca			
Gastropoda	1.559×10^{9}	3.734×10^{8}	1.932×10^{9}
Pelecypoda	3.529×10^{8}	2.115×10^{6}	3.550×10^{8}
Isopoda			
Aegathoa sp.	7.210×10^{6}	1.486×10^{6}	8.696×10^{6}
Cirripedia			
Balanus sp.	5.011×10^{8}	3.070×10^{8}	8.081×10^{8}

Appendix 6C-8. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Polychaeta			
Nereidae	2.369×10^7	1.381×10^7	3.750×10^7
Spionidae	3.422×10^7	5.892×10^7	9.314×10^7
Unidentified	5.287×10^7	3.188×10^7	1.460×10^8
Brachiopoda	4.391×10^8	1.203×10^8	5.594×10^8
Echinodermata			
Unidentified	0	1.387×10^8	1.387×10^8
Urochordata	6.200×10^6	0	6.200×10^6
Phoronida	0	1.284×10^7	1.284×10^7
TOTAL	5.286×10^{10}	8.514×10^9	6.137×10^{10}

Appendix 6C-9. Estimated Number of Meroplankton Entrained During September, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total Entrained
Stomatopoda			
Squilla sp.	0	3.723×10^6	3.723×10^6
Decapoda			
Unidentified	0	3.723×10^6	3.723×10^6
Penaeidae			
Penaeus duorarum	5.403×10^6	0	5.403×10^6
Pasiphaeidae			
Leptochela spp.	3.641×10^7	7.837×10^6	4.425×10^7
Palaemonidae			
Periclimenes americanus	7.362×10^7	0	7.362×10^7
Periclimenes spp.	1.009×10^9	3.533×10^8	1.362×10^9
Palaemonetes intermedius	1.510×10^8	1.141×10^7	1.624×10^8
Palaemonetes pugio/ vulgaris	4.021×10^6	0	4.021×10^6
Unidentified sp. C	1.579×10^7	3.461×10^6	1.925×10^7
Alpheidae			
Unidentified sp. A	3.041×10^8	7.895×10^7	3.830×10^8
Unidentified sp. B	0	1.110×10^6	1.110×10^6
Unidentified sp. C	3.426×10^7	2.221×10^6	3.648×10^7
Unidentified	1.846×10^7	0	1.846×10^7
Ogyrididae			
Ogyrides limicola	6.237×10^8	3.061×10^7	6.543×10^8
Hippolytidae			
Hippolyte spp.	1.370×10^8	2.684×10^7	1.638×10^8
Latreutes parvulus	8.792×10^8	1.017×10^8	9.809×10^8
Tozeuma carolineuse	5.204×10^4	0	5.204×10^4
Unidentified sp. D	0	1.110×10^6	1.110×10^6
Unidentified	1.846×10^7	0	1.846×10^7

Appendix 6C-9. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Processidae			
Ambidexter symmetricus	2.298×10^9	6.744×10^8	2.972×10^9
Processa spp.	3.292×10^7	2.528×10^7	5.820×10^7
Caridea			
Unidentified	2.252×10^8	3.788×10^7	2.631×10^8
Callianassidae			
Upogebia affinis	7.352×10^9	1.160×10^9	8.512×10^9
Unidentified sp. D	0	1.045×10^7	1.045×10^7
Porcellanidae			
Petrolisthes spp.	2.174×10^8	2.372×10^7	2.411×10^8
Polyonyx gibbesi	2.208×10^{10}	4.134×10^8	2.249×10^{10}
Paguridae			
Pagurus longicarpus	5.375×10^5	0	5.375×10^5
Unidentified sp. A	5.165×10^7	3.971×10^7	9.136×10^7
Unidentified	0	3.723×10^6	3.723×10^6
Leucosiidae			
Persephone aquilonaris	1.114×10^8	1.580×10^6	1.133×10^8
Xanthidae			
Eurypanopeus depressus	2.703×10^9	8.645×10^8	3.567×10^9
Hexapanopeus angustifrons	4.599×10^9	8.878×10^8	5.487×10^9
Menippe mercenaria	1.742×10^9	4.965×10^8	2.238×10^9
Neopanope texana texana	1.294×10^{10}	2.686×10^9	1.563×10^{10}
Panopeus herbstii	7.759×10^8	8.142×10^7	8.573×10^8
Rithropanopeus harrisii	1.770×10^8	1.935×10^7	1.963×10^8
Unidentified	2.594×10^9	4.153×10^8	3.009×10^9

Appendix 6C-9. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Pinnotheridae			
Pinnixa chaetopterana	8.991×10^{8}	3.018×10^{8}	1.201×10^{9}
Pinnixa sayana	3.945×10^{10}	2.677×10^{9}	4.213×10^{10}
Pinnotheres maculatus	3.318×10^{8}	1.165×10^{8}	4.483×10^{8}
Laomediidae			
Unidentified	0	1.850×10^{6}	1.850×10^{6}
Grapsidae			
Sesarma cinereum	2.275×10^{8}	3.983×10^{7}	2.673×10^{8}
Sesarma reticulatum	1.668×10^{8}	5.584×10^{7}	2.226×10^{8}
Ocypodidae			
Uca spp.	4.170×10^{8}	2.585×10^{8}	6.755×10^{8}
Majidae			
Libinia dubia	9.426×10^{7}	1.156×10^{7}	1.058×10^{8}
Brachyura			
Unidentified	3.720×10^{7}	0	3.720×10^{7}
Mollusca			
Gastropoda	3.479×10^{9}	6.528×10^{8}	4.132×10^{9}
Pelecypoda	9.339×10^{7}	2.394×10^{7}	1.173×10^{8}
Cirripedia			
Balanus sp.	1.049×10^{9}	6.250×10^{7}	1.111×10^{9}
Polychaeta			
Nereidae	6.316×10^{7}	0	6.316×10^{7}
Spionidae	1.263×10^{8}	3.737×10^{7}	1.637×10^{8}
Brachiopoda	2.954×10^{8}	6.347×10^{7}	3.589×10^{8}
Urochordata	3.720×10^{7}	0	3.720×10^{7}
Phoronida	5.375×10^{5}	0	5.375×10^{5}
TOTAL	1.080×10^{11}	1.277×10^{10}	1.209×10^{11}

Appendix 6C-10. Estimated Number of Meroplankton Entrained During October, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Pasiphaeidae			
Leptochela serritorbita	3.800×10^7	6.835×10^6	4.484×10^7
Leptochela spp.	5.821×10^7	0	5.821×10^7
Palaemonidae			
Periclimenes americanus	5.805×10^7	6.835×10^6	6.489×10^7
Periclimenes spp.	6.681×10^8	7.423×10^7	7.423×10^8
Palaemonetes floridanus	3.784×10^7	0	3.784×10^7
Palaemonetes intermedius	2.999×10^7	7.730×10^6	3.772×10^7
Palaemonetes pugio/vulgaris	1.245×10^8	1.043×10^6	1.255×10^8
Unidentified sp. C	3.164×10^7	6.233×10^7	9.397×10^7
Unidentified	1.590×10^7	0	1.590×10^7
Alpheidae			
Unidentified sp. A	1.744×10^8	4.351×10^7	2.179×10^8
Unidentified sp. B	0	4.634×10^5	4.634×10^5
Unidentified sp. C	3.784×10^7	0	3.784×10^7
Ogyrididae			
Ogyrides limicola	2.024×10^9	3.529×10^7	2.059×10^9
Hippolytidae			
Hippolyte spp.	7.570×10^7	3.000×10^7	1.507×10^8
Latreutes parvulus	4.190×10^8	2.409×10^7	4.431×10^8
Tozeuma carolinense	1.747×10^7	0	1.747×10^7
Unidentified sp. D	3.230×10^5	4.634×10^5	7.864×10^5
Unidentified	1.615×10^5	0	1.615×10^5
Processidae			
Ambidexter symmetricus	1.039×10^9	3.490×10^8	1.388×10^9
Processa spp.	3.678×10^7	1.158×10^7	4.836×10^7
Caridea			
Unidentified	0	7.295×10^6	7.295×10^6

Appendix 6C-10. Estimated Number of Meroplankton Entrained During October, 1976. continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Callianassidae			
Upogebia affinis	1.095×10^{9}	3.494×10^{8}	1.444×10^{9}
Unidentified sp. D	3.784×10^{7}	0	3.784×10^{7}
Unidentified	0	2.897×10^{6}	2.897×10^{6}
Porcellanidae			
Petrolisthes spp.	1.541×10^{8}	1.372×10^{7}	1.678×10^{8}
Polyonyx gibbesi	1.026×10^{10}	6.877×10^{8}	1.095×10^{10}
Paguridae			
Pagurus longicarpus	5.251×10^{7}	0	5.251×10^{7}
Unidentified sp. A	1.606×10^{7}	2.897×10^{6}	1.896×10^{7}
Unidentified	3.116×10^{7}	0	3.116×10^{7}
Leucosiidae			
Persephone aquilonaris	7.462×10^{7}	3.698×10^{6}	7.832×10^{7}
Xanthidae			
Eurypanopeus depressus	2.955×10^{8}	1.200×10^{8}	4.155×10^{8}
Hexapanopeus augustifrons	2.130×10^{9}	4.159×10^{8}	2.546×10^{9}
Menippe mercenaria	4.529×10^{8}	9.596×10^{7}	5.489×10^{8}
Neopanope texana texana	1.147×10^{10}	1.409×10^{9}	1.288×10^{10}
Panopeus herbstii	3.000×10^{8}	8.193×10^{6}	3.082×10^{8}
Rithropanopeus harrisii	7.842×10^{8}	4.836×10^{7}	8.326×10^{8}
Unidentified	2.708×10^{8}	5.023×10^{8}	7.731×10^{8}
Pinnotheridae			
Pinnixa chaetopterana	2.457×10^{9}	3.762×10^{8}	2.833×10^{9}
Pinnixa sayana	8.028×10^{10}	7.078×10^{9}	8.736×10^{10}
Pinnotheres maculatus	3.220×10^{8}	8.327×10^{7}	4.053×10^{8}
Unidentified sp. A	0	1.854×10^{6}	1.854×10^{6}
Unidentified	2.792×10^{8}	0	2.792×10^{8}
Laomediidae			
Unidentified	0	8.018×10^{5}	8.018×10^{5}

Appendix 6C-10. Estimated Number of Meroplankton Entrained During October, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Grapsidae			
Sesarma cinereum	1.086×10^{8}	1.168×10^{7}	1.203×10^{8}
Sesarma reticulatum	4.492×10^{7}	6.140×10^{6}	5.106×10^{7}
Ocypodidae			
Uca spp.	3.041×10^{7}	3.489×10^{7}	6.530×10^{7}
Majidae			
Libinia dubia	3.230×10^{5}	1.390×10^{6}	1.713×10^{6}
Mollusca			
Gastropoda	1.310×10^{9}	1.964×10^{8}	1.506×10^{9}
Pelecypoda	2.747×10^{8}	1.589×10^{8}	4.336×10^{8}
Isopoda			
Aegathoa sp.	0	4.634×10^{5}	4.634×10^{5}
Cirripedia			
Balanus sp.	2.196×10^{8}	1.867×10^{8}	4.063×10^{8}
Polychaeta			
Spionidae	0	1.880×10^{7}	1.880×10^{7}
Syllidae	1.909×10^{7}	0	1.909×10^{7}
Unidentified	0	9.848×10^{6}	9.848×10^{6}
Brachiopoda	1.451×10^{7}	3.684×10^{7}	5.135×10^{7}
Echinodermata	0	5.850×10^{7}	5.850×10^{7}
Phoronida	1.451×10^{7}	0	1.451×10^{7}
Total	1.177×10^{11}	1.258×10^{10}	1.304×10^{11}

Appendix 6C-11. Estimated Number of Meroplankton Entrained During November, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Merostomata			
Limulus polyphemus	0	5.344×10^6	5.344×10^6
Penaeidae			
Penaeus duorarum	1.206×10^6	0	1.206×10^6
Pasiphaeidae			
Leptochela serritorbita	4.673×10^6	1.674×10^6	6.347×10^6
Leptochela spp.	2.503×10^6	8.505×10^5	3.354×10^6
Palaemonidae			
Periclimenes americanus	0	6.532×10^6	6.532×10^6
Periclimenes spp.	3.383×10^7	4.401×10^7	7.784×10^7
Palaemonetes intermedius	0	8.580×10^6	8.850×10^6
Palaemonetes longicaudatus	1.723×10^6	2.065×10^6	3.788×10^6
Palaemonetes pugio/ vulgaris	5.547×10^6	9.841×10^5	6.531×10^6
Unidentified sp. C	8.956×10^6	1.854×10^7	2.750×10^7
Unidentified	1.206×10^6	0	1.206×10^6
Alpheidae			
Unidentified sp. A	7.509×10^6	7.698×10^6	1.521×10^7
Unidentified sp. B	2.653×10^6	7.207×10^5	3.374×10^6
Ogyrididae			
Ogyrides limicola	4.432×10^6	6.829×10^6	1.126×10^7
Hippolytidae			
Hippolyte zostericola	1.688×10^6	8.505×10^5	2.539×10^6
Hippolyte spp.	2.403×10^7	1.278×10^7	3.681×10^7
Latreutes parvulus	2.164×10^7	1.179×10^7	3.343×10^7
Thor floridanus	0	2.429×10^5	2.429×10^5
Tozeuma carolinense	3.467×10^6	0	3.467×10^6
Unidentified sp. D	5.006×10^6	1.135×10^5	5.120×10^6
Unidentified	2.503×10^6	4.858×10^5	2.989×10^6

Appendix 6C-11. Estimated Number of Meroplankton Entrained During November, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Processidae			
Ambidexter symmetricus	2.708×10^7	5.745×10^7	8.453×10^7
Processa spp.	9.888×10^6	2.837×10^6	1.272×10^7
Caridea			
Unidentified	9.646×10^5	1.268×10^6	2.232×10^6
Callianassidae			
Upogebia affinis	3.455×10^7	3.669×10^7	7.124×10^7
Unidentified	0	7.094×10^5	7.094×10^5
Porcellanidae			
Petrolisthes spp.	2.503×10^6	1.674×10^6	4.177×10^6
Polyonyx gibbesi	6.640×10^9	1.686×10^8	6.809×10^9
Paguridae			
Pagurus longicarpus	1.359×10^7	3.158×10^6	1.675×10^7
Unidentified sp. A	2.503×10^6	9.523×10^5	3.455×10^6
Leucosiidae			
Persephone aquilonaris	1.688×10^6	1.560×10^6	3.248×10^6
Unidentified	0	6.072×10^5	6.072×10^5
Xanthidae			
Eurypanopeus depressus	6.602×10^6	1.139×10^7	1.799×10^7
Hexanopanopeus angustifrons	9.910×10^7	6.540×10^7	1.645×10^8
Menippe mercenaria	1.585×10^7	9.525×10^6	2.538×10^7
Neopanopeus texana texana	1.037×10^9	5.215×10^8	1.558×10^9
Panopeus herbstii	0	1.163×10^6	1.163×10^6
Rithropanopeus harrisii	6.645×10^7	2.667×10^7	9.312×10^7
Unidentified	5.818×10^7	1.169×10^8	1.751×10^8
Pinnotheridae			
Pinnixa chaetopterana	4.972×10^7	8.321×10^7	1.329×10^8
Pinnixa sayana	2.475×10^9	1.169×10^9	4.104×10^9
Pinnotheres maculatus	2.237×10^7	1.741×10^7	3.978×10^7
Unidentified sp. A	0	4.540×10^5	4.540×10^5

Appendix 6C-11. Estimated Number of Meroplankton Entrained During November, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Grapsidae			
Sesarma cinereum	1.929×10^{6}	1.649×10^{6}	3.578×10^{6}
Sesarma reticulatum	0	1.504×10^{6}	1.504×10^{6}
Ocypodidae			
Uca spp.	0	3.153×10^{6}	3.153×10^{6}
Majidae			
Libinia dubia	5.006×10^{6}	4.713×10^{6}	9.719×10^{6}
Brachyura			
Unidentified	7.235×10^{5}	0	7.235×10^{5}
Mollusca			
Gastropoda	1.110×10^{10}	1.080×10^{9}	1.218×10^{10}
Pelecypoda	5.064×10^{6}	3.710×10^{7}	4.217×10^{7}
Isopoda			
Aegethoa sp.	2.894×10^{6}	1.590×10^{7}	1.880×10^{7}
Cirripedia			
Balanus sp.	1.454×10^{8}	5.743×10^{8}	7.197×10^{8}
Polychaeta			
Nereidae	1.206×10^{6}	0	1.206×10^{6}
Spioinidae	0	1.220×10^{6}	1.220×10^{6}
Syllidae	1.929×10^{6}	0	1.929×10^{6}
Unidentified	2.894×10^{6}	2.412×10^{6}	5.306×10^{6}
Brachipoda	0	4.794×10^{6}	4.794×10^{6}
Echinodermata	0	1.433×10^{7}	1.433×10^{7}
Total	2.196×10^{10}	4.629×10^{9}	2.660×10^{10}

Appendix 6C-12. Estimated Number of Meroplankton Entrained During December, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Merostomata			
Limulus polyphemus	0	1.550×10^6	1.550×10^6
Peuaeidae			
Penaeus duorarum	3.742×10^5	0	3.742×10^5
Pasiphaeidae			
Leptochela serritorbita	1.243×10^7	0	1.243×10^7
Leptochela spp.	0	2.392×10^5	2.392×10^5
Palaemonidae			
Peridimenes americanus	1.623×10^6	1.600×10^6	3.223×10^6
Perichmenes spp.	5.838×10^6	8.915×10^6	1.475×10^7
Palaemonetes intermedius	1.988×10^7	2.318×10^7	4.306×10^7
Palaemonetes longicaudatus	2.627×10^6	8.147×10^5	3.442×10^6
Palaemonetes pugio/ vulgaris	1.721×10^6	2.050×10^5	1.926×10^6
Unidentified sp. C	4.491×10^5	1.039×10^6	1.488×10^6
Unidentified	3.742×10^5	0	3.742×10^5
Alpheidae			
Unidentified sp. A	0	1.117×10^6	1.117×10^6
Unidentified sp. B	8.233×10^5	2.174×10^5	1.041×10^6
Ogyrididae			
Ogyrides limicola	2.222×10^6	2.050×10^5	2.427×10^6
Hippolytidae			
Hippolyte zostericola	5.239×10^5	2.392×10^5	7.631×10^5
Hippolyte spp.	1.782×10^8	6.520×10^7	2.434×10^8
Latreutes parvulus	2.589×10^7	4.743×10^6	3.063×10^7
Thor floridanus	0	6.833×10^4	6.833×10^4
Tozeuma carolinense	2.994×10^5	1.366×10^5	4.360×10^5
Unidentified	0	6.833×10^4	6.833×10^4

Appendix 6C-12. Estimated Number of Meroplankton Entrained During December, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Processidae			
Amdidexter symmetricus	1.956×10^{7}	6.637×10^{6}	2.620×10^{7}
Processa spp.	7.003×10^{6}	1.399×10^{5}	7.143×10^{6}
Caridea			
Unidentified	2.994×10^{5}	3.247×10^{6}	3.546×10^{6}
Callinnassidae			
Upogebia affinis	8.939×10^{6}	5.140×10^{6}	1.408×10^{7}
Porcellanidae			
Petrolisthes spp.	1.056×10^{6}	0	1.056×10^{6}
Polyonyx gibbesi	1.071×10^{7}	5.860×10^{6}	1.657×10^{7}
Unidentified	0	3.731×10^{5}	3.731×10^{5}
Paguridae			
Pagurus longicarpus	4.121×10^{7}	1.495×10^{7}	5.616×10^{7}
Pagurus pollicaris	0	2.340×10^{5}	2.340×10^{5}
Unidentified sp. A	1.623×10^{6}	5.831×10^{5}	2.206×10^{6}
Leucosiidae			
Persephone aquilonaris	5.239×10^{5}	2.392×10^{5}	7.631×10^{5}
Portunidae			
Callinectes sapidus	0	2.340×10^{5}	2.340×10^{5}
Unidentified	1.623×10^{6}	1.708×10^{5}	1.794×10^{6}
Xanthidae			
Eurypanopeus depressus	1.712×10^{6}	1.218×10^{6}	2.930×10^{6}
Hexanopeus augustifrons	2.333×10^{7}	7.827×10^{6}	3.116×10^{7}
Menippe mercenaria	9.729×10^{5}	1.059×10^{6}	2.032×10^{6}
Neopanope texana texana	2.534×10^{8}	1.035×10^{8}	3.569×10^{8}
Panepeus herbstii	7.707×10^{6}	4.681×10^{5}	3.646×10^{8}
Rithropanopeus harrisii	1.694×10^{7}	5.581×10^{6}	2.252×10^{7}
Unidentified	1.011×10^{7}	5.401×10^{6}	1.551×10^{7}

Appendix 6C-12. Estimated Number of Meroplankton Entrained During December, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Pinnotheridae			
Pinnixa chaetopterana	6.736×10^5	8.273×10^5	1.501×10^6
Pinnixa sayana	7.566×10^7	7.830×10^6	8.349×10^7
Pinnotheres maculatus	5.388×10^6	1.400×10^6	6.788×10^6
Grupsidae			
Sesarma cinereum	5.987×10^5	1.366×10^5	7.353×10^5
Ocypodidae			
Uca spp.	0	1.366×10^5	1.366×10^5
Majidae			
Libinia dubia	2.028×10^6	2.049×10^6	4.077×10^6
Brachyura			
Unidentified	2.245×10^5	0	2.245×10^5
Mollusca			
Gastropoda	7.341×10^9	6.822×10^8	8.023×10^9
Pelecypoda	7.504×10^7	5.726×10^7	1.323×10^8
Isopoda			
Aegathoa sp.	3.737×10^6	6.804×10^6	1.054×10^7
Cirripedia			
Balanus sp.	6.951×10^8	2.448×10^8	9.399×10^8
Polychaeta			
Nereidae	8.142×10^5	3.506×10^5	1.165×10^6
Spionidae	0	1.890×10^6	1.890×10^6
Syllidae	8.306×10^6	6.317×10^5	8.938×10^6
Unidentified	8.981×10^5	0	8.981×10^5
Urochordata	3.432×10^6	5.805×10^7	6.148×10^7
Total	8.873×10^9	1.337×10^9	1.021×10^{10}

Appendix 6C-13. Estimated Number of Meroplankton Entrained During January, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Merostomata			
Limulus polyphemus	0	2.892×10^5	2.892×10^5
Palaemonidae			
Unidentified sp. C	0	7.229×10^5	7.229×10^5
Alpheidae			
Unidentified sp. B	0	2.892×10^5	2.892×10^5
Hippolytidae			
Hippolyte spp.	0	2.313×10^6	2.313×10^6
Latreutes paruulus	0	1.012×10^6	1.012×10^6
Processa spp.			
Processa spp.	6.547×10^6	8.673×10^5	7.414×10^6
Callinuassidae			
Upogebia affinis	0	2.892×10^5	2.892×10^5
Porcellanidae			
Petrolisthes spp.	6.547×10^6	0	6.547×10^6
Polyonyx gibbesi	0	1.446×10^6	1.446×10^6
Unidentified	0	2.313×10^6	2.313×10^6
Paguridae			
Pagurus longicarpus	2.292×10^7	9.544×10^6	3.246×10^7
Unidentified sp. A	0	2.892×10^5	2.892×10^5
Xanthidae			
Eurypanopeus depressus	2.728×10^6	4.192×10^6	6.920×10^6
Hexapanopeus angustifrons	6.547×10^6	1.301×10^7	1.956×10^7
Neopanope texana texana	2.728×10^6	1.879×10^6	4.607×10^6
Unidentified	0	5.783×10^5	5.783×10^5
Pinnotheridae			
Pinnixa chaetopterana	0	2.892×10^5	2.892×10^5

Appendix 6C-13. Estimated Number of Meroplankton Entrained During January, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Mollusca			
Gastropoda	1.124×10^9	3.527×10^8	1.477×10^9
Pelecypoda	8.075×10^7	2.718×10^8	3.525×10^8
Isopoda			
Aegathoa sp.	0	8.673×10^5	8.673×10^5
Cirripedia			
Balanus sp.	1.375×10^9	3.387×10^8	1.714×10^9
Polychaeta			
Nereidae	2.728×10^6	7.229×10^5	3.451×10^6
Spionidae	0	1.027×10^7	1.027×10^7
Syllidae	0	2.892×10^5	2.892×10^5
Urochordata	2.128×10^7	2.221×10^8	2.434×10^8
Total	2.652×10^9	1.237×10^9	3.889×10^9

Appendix 6C-14. Estimated Number of Meroplankton Entrained During February, 197 .

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Merostomata			
Limulus polyphemus	0	5.597×10^4	5.597×10^4
Palaemonidae			
Palaemonetes intermedius	1.341×10^7	2.626×10^6	1.604×10^7
Palaemonetes pugio/vulgaris	1.559×10^7	0	1.559×10^7
Unidentified sp. C	0	1.085×10^6	1.085×10^6
Alpheidae			
Unidentified sp. B	0	5.597×10^4	5.597×10^4
Hippolytidae			
Hippolyte spp.	1.266×10^8	4.089×10^7	9.344×10^7
Latreutes paruulus	0	1.959×10^5	1.959×10^5
Processidae			
Ambidexter symmetricus	0	8.406×10^5	8.406×10^5
Processa spp.	1.267×10^6	1.679×10^5	9.771×10^6
Callianassidae			
Upogebia affinis	2.963×10^7	3.523×10^6	3.315×10^7
Porcellanidae			
Petrolisthes spp.	1.267×10^6	0	1.267×10^6
Polyonyx gibbesi	0	4.900×10^5	4.900×10^5
Unidentified	0	4.477×10^5	4.477×10^5
Paguridae			
Pagurus longicarpus	1.523×10^8	5.257×10^7	2.049×10^8
Unidentified sp. A	1.559×10^7	3.838×10^6	1.943×10^7
Portunidae			
Callinectes sp. A	0	3.887×10^6	3.887×10^6
Xanthidae			
Eurypanopeus depressus	1.709×10^8	1.404×10^8	3.113×10^8

Appendix 6C-14. Estimated Number of Meroplankton Entrained During February, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Hexapanopeus angustifrons	9.637×10^7	1.446×10^8	2.410×10^8
Neopanope texana texana	8.786×10^7	3.335×10^7	1.212×10^8
Panopeus herbstii	0	1.093×10^7	1.093×10^7
Rithropanopeus harrisii	0	1.061×10^7	1.061×10^7
Unidentified	1.029×10^8	2.732×10^7	1.302×10^8
Pinnotheridae			
Pinnixa chaetopterana	3.181×10^7	2.997×10^6	3.481×10^7
Pinnixa sayana	4.533×10^9	1.850×10^9	6.383×10^9
Majidae			
Libinia dubia	7.795×10^6	2.626×10^6	1.042×10^7
Mollusca			
Gastropoda	2.176×10^8	9.758×10^7	3.152×10^8
Pelecypoda	1.030×10^8	7.708×10^7	1.801×10^8
Isopoda			
Aegathoa sp.	0	1.679×10^5	1.679×10^5
Cirripedia			
Balanus sp.	2.112×10^9	1.437×10^9	3.549×10^9
Polychaeta			
Nereidae	5.280×10^5	1.399×10^5	6.679×10^5
Spionidae	3.181×10^7	4.528×10^7	7.709×10^7
Syllidae	1.622×10^7	5.307×10^6	2.153×10^7
Echinodermata	8.875×10^8	7.048×10^7	9.580×10^8
Urochordata	4.119×10^6	4.299×10^7	4.710×10^7
Total	8.759×10^9	4.110×10^9	1.287×10^{10}

Appendix 6C-15. Estimated Number of Meroplankton Entrained During March, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Palaemonidae			
Palaemonetes intermedius	1.890×10^7	3.701×10^6	2.260×10^7
Palaemonetes pugio/ vulgaris	2.197×10^7	0	2.197×10^7
Unidentified sp. C	0	1.332×10^6	1.332×10^6
Hippolytidae	0	5.699×10^7	5.699×10^7
Hippolyte spp.	1.784×10^8	0	1.784×10^8
Processidae			
Ambidexter symmetricus	0	1.184×10^6	1.184×10^6
Callianassidae			
Upogebia affinis	4.174×10^7	4.885×10^6	4.663×10^7
Porcellanidae			
Polyonyx gibbesi	0	2.961×10^5	2.961×10^5
Paguridae			
Pagurus longicarpus	2.803×10^8	7.148×10^7	2.798×10^8
Unidentified sp. A	2.197×10^7	5.329×10^6	2.730×10^7
Portunidae			
Callinectes sp. A	0	5.477×10^6	5.477×10^6
Xanthidae			
Eurypanopeus depressus	2.408×10^8	1.967×10^8	4.375×10^8
Hexanopeus angustifrons	1.340×10^8	2.003×10^8	3.343×10^8
Neopanopeus texana texana	1.231×10^8	4.648×10^7	1.696×10^8
Panopeus herbstii	0	1.539×10^7	1.539×10^7
Rithropanopeus harrisii	0	1.495×10^7	1.495×10^7
Unidentified	1.450×10^8	3.834×10^7	1.833×10^8
Pinnotheridae			
Pinnixa chaetopterana	4.482×10^7	4.145×10^6	4.896×10^6
Pinnixa sayana	6.387×10^9	2.606×10^9	8.993×10^9

Appendix 6C-15. Estimated Number of Meroplankton Entrained During March, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Majidae			
Libinia dubia	1.098×10^7	3.701×10^6	1.468×10^7
Mollusca			
Gastropoda	0	4.130×10^7	4.130×10^7
Pelecypoda	1.231×10^8	3.449×10^7	1.576×10^8
Cirripedia			
Balanus sp.	2.601×10^9	1.933×10^9	4.534×10^9
Polychaeta			
Spionidae	4.482×10^7	6.101×10^7	1.058×10^8
Syllidae	2.285×10^7	7.399×10^6	3.025×10^7
Echinodermata	1.251×10^9	9.932×10^7	1.350×10^9
Total	1.162×10^{10}	5.453×10^9	1.707×10^{10}

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CHAPTER SEVEN

A STUDY ON THE IMPINGEMENT OF FISHES AND MACROINVERTEBRATES AT THE BIG BEND STEAM ELECTRIC STATION, TAMPA, FLORIDA

By

RONALD PEEKSTOK
DANIEL A. PAGE
LAWRENCE E. HAYNES

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LIST OF PARTICIPANTS

PRINCIPAL INVESTIGATOR:	Ronald M. Peekstok B.S. Staff Biologist
RESEARCH ASSISTANTS:	Daniel A. Page B.S. Staff Biologist
	Lawrence E. Haynes Marine Science Technician
	Robert W. Whitley Marine Science Technician
REVISION EDITORS:	Gary S. Comp B.A. Staff Biologist
	Richard A. Lotspeich M.S. Staff Biologist

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INTRODUCTION

General

Fish kills due to impingement on power plant cooling water intake screens have been documented for a large number of power plants (Landry and Strawn, 1974; Edwards, Hunt, Miller and Senic, 1975; Grimes, 1975; Benda, 1976; Bernhard and Latvaites, 1976). Impingement usually occurs when fish become entrained in the current of cooling water being drawn into power plants (at Big Bend this current is 0.59 m/sec. at the screen opening). Trash racks are usually set up to catch large fish and debris but the actual intake screens impinge many smaller fish, invertebrates and debris. Some fish and invertebrates become impinged after being attracted to an intake structure for possible protection or to feed on already impinged organisms and encrusting molluscs and crustaceans. Pumping sounds have also been suggested to attract fish to intake structures (Clark and Brownell, 1973).

The impact of power plant impingement of fish and invertebrates is certainly site specific and difficult to generally assess. Clark and Brownell (1973) rated impingement as one of the major problems faced by power plants located in coastal areas. Conversely, several studies have concluded that impingement rates are either negligible or do not represent significant damage to resident populations (Landry and Strawn, 1974; Voightlander et al., 1976; Bernhardt and Latvaitis, 1976; Mather et al., 1977). In general, most reports on impingement have failed to adequately assess actual impact. This failure has usually been due either to a lack of preoperational data or to a general lack of knowledge of standing crop, fecundity, and natural mortality rates of the local fish and invertebrates.

Specific Objectives

The present paper is the result of 15 consecutive months of sampling at Units 1 and 2 of Big Bend Station. This sampling scheme was designed to fulfill monitoring requirements set by the Environmental Protection Agency and included a monitoring of all impinged organisms over 24 hour periods once every two weeks.

The specific objectives of monitoring the kinds and numbers of organisms impinged on the intake screens at Big Bend Station have been:

1. to determine the total number of organisms impinged per unit of sampling time;
2. to average these data to give estimated seasonal daily impingement rates;

3. to determine size-class distribution of selected species;

4. to elucidate species dominance of impinged organisms; and

5. to identify differences in night impingement rates with and without lighting of the intake structure.

Information from each of the above categories has been used to evaluate and describe the impact of impingement at Big Bend. Data derived from objectives 1-4 have been compared with local commercial catch data and literature on the natural abundance and seasonal distribution of species impinged (e.g. does impingement trap a large number of species that are rarely found at the site, or possibly, small numbers of a species that is found abundantly year round, etc.).

Sampling was on Units 1 and 2 only, as the study was meant to document effects of these units. These units are closest to the entrance to the intake channel and probably represent the worst case. Also, Unit 3 was not in operation until almost 1/3 of our sampling was completed.

The Site and Intake Structure

Tampa Electric Company's Big Bend Station is located on the southeast shore of Hillsborough Bay in the Tampa Bay system. The plant intake is located near the east end of a .04 km intake channel (Figure 7.1). Approximately 240,000 gpm of cooling water is pumped through each of the three units independent of unit load. In an effort to reduce impingement, the vertical travelling screens (0.38" mesh) are hung perpendicular to the intake channel (Figure 7.2). As the screens become clogged, they are rotated and cleaned by a jet of water which frees impinged organisms, forcing them into a sluicing trough and thence to a holding tank from which they are periodically collected and then buried. A trash rack (vertical bars 3" apart) surrounds the intake screens to filter the top layer of floating debris.

Limitations

This study is primarily limited by a paucity of historical data for comparative purposes. Although there is no information on the standing stock of any fish or macroinvertebrate population in Tampa Bay, estimates of seasonal abundance of dominant species in the study area is presented in Chapter 8. The basic task therefore has been to compare the number of species and individuals that were captured per unit effort or per unit time with data such as average seasonal abundance and commercial catch data. Such relative impact assessment, although augmented by comparisons with available literature concerning other areas is, necessarily, subjective and qualitative in nature.

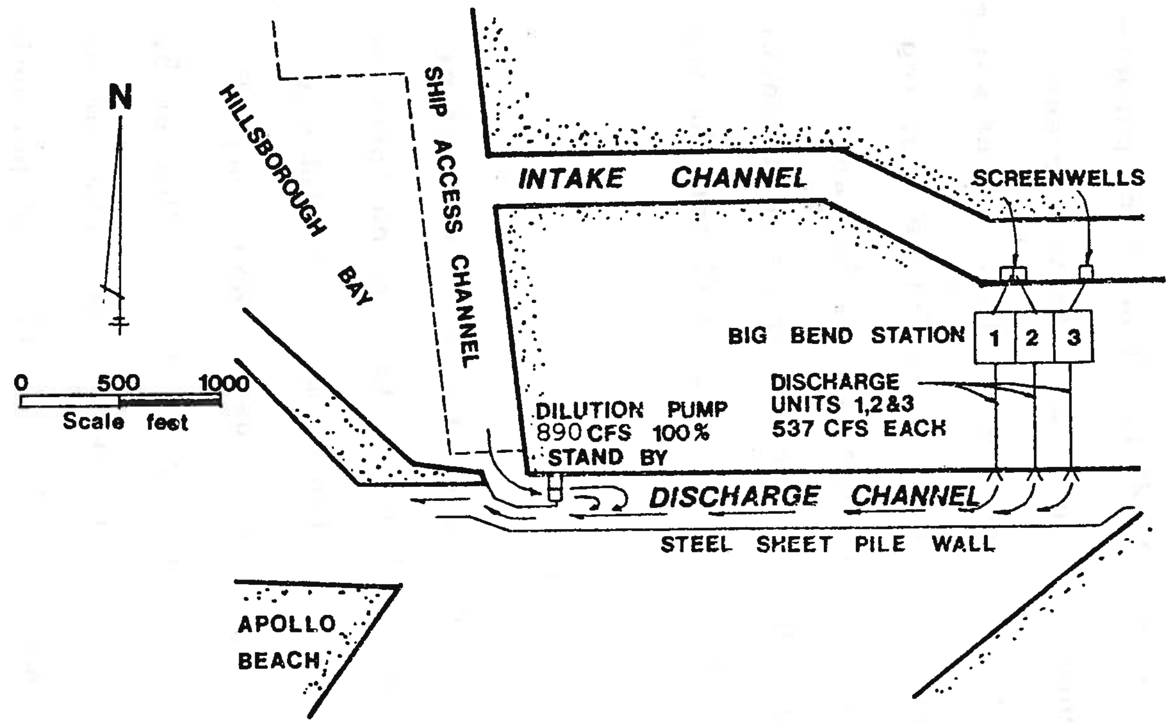

Figure 7.1. Diagram of intake channel and location of intakes for Units 1 and 2.

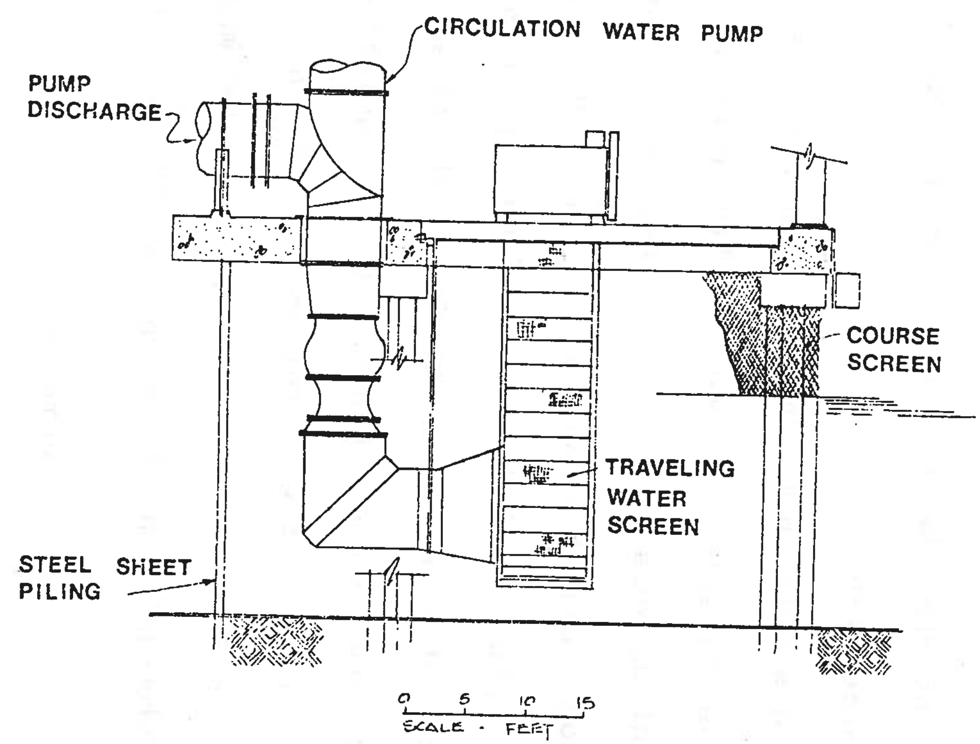

Figure 7.2. Circulating Water intake. Big Bend Station, Tampa Electric Company.

Two technical limitations are:

1. It was not always possible to determine whether an organism died from inpingement or from other causes (i.e. was dead before impingement). The major speculative cause of death other than impingement was cold water due to a severe winter (see Results). Some other inaccuracies in our estimates have probably been incurred due to the number of crabs feeding on impinged fish.
2. Only a single unit (Unit 1 or Unit 2) was sampled during any given 24 hour sampling period. Entrained organisms pass these units first in the intake canal. Although all three units pump equal volumes of water (and volume is independent of unit load in all three), we cannot rule out some behavioral attraction to one unit more than any other and, consequently, our data can only structly be interpreted for Unit 1 or Unit 2. However in an attempt to appreciate the impact of the plant as a whole (All 3 Units), one may triple the per unit estimates.

METHODS

The vertical travelling screens at Big Bend (Units 1 or 2) were sampled once every two weeks from January, 1976 through March, 1977. Unit 1 was the primary unit sampled. Whenever Unit 1 was offline, the screens of Unit 2 were sampled. The intake screens of both units are on the same intake structure within a few feet of each other. Impingement samples were collected by plant personnel in the following manner:

1. At 0001 hours the screens were washed to begin the sampling period.
2. At 0600, 1200, 1800 and 2400 hours the screens were washed for two full cycles. The screen wash was filtered into a 0.38 inch mesh basket and the resultant filtrate was placed into a labeled container.

Laboratory Procedures

Laboratory personnel separated fish and macroinvertebrates from the encrusting organisms and other debris. Each individual was then identified using accepted taxonomic keys (Williams, 1965; Felder, 1973; Cliburn, 1974; Gallaway, Parker and Moore, 1972), weighed and measured. Fish standard length, squid pen (gladii) length, shrimp total length, and decapod carapace width (carapace length in *Limulus polyphemus*) were measured to the nearest millimeter (*L. polyphemus* to nearest 0.5 centimeter). Individuals with a biomass of less than 150.0 grams were weighed to the nearest 0.1 gram on a Torbal Model St-1 balance or an Ohaus Model 311 balance. Larger individuals were weighed to the nearest 0.5 g. on a Mettler balance (Model P-6).

Qualitative observations were made on the ability of selected species to survive 24 hours after impingement. Organisms were placed in aquaria kept at room temperature and observed intermittently over 24 hours.

Effects of Intake Structure Lighting

A three month period (January-March, 1976) was used to study the effects of intake structure lighting on impingement rates. An additional five nights (60 hours) were sampled when the intake struoture lights were off. Each of these five samples were collected within a few nights of the regular 24 hour collections. Samples were processed as indicated above.

RESULTS AND DISCUSSION

Invertebrates

Relative Abundance and Seasonality

A total of 9,382 invertebrate organisms representing 27 species were collected from the travelling screens (Unit 1 or Unit 2) from a total of 31 days (744 hours) of sampling from January, 1976 to March, 1977. This resulted in an average of 302.6 invertebrates impinged per sampling day (12.6/hour).

The following six species comprised 84.8% of the total number of invertebrates collected: *Penaeus duorarum* (pink shrimp), _Callinectes sapidus_ (blue crab), _Limulus polyphemus_ (horseshoe crab), _Portunus gibbesii_ (a portunid crab), _Lolliguncula brevis_ (brief squid) and _Squilla empusa_ (mantis shrimp). Of all invertebrates collected, _P. duorarum_ accounted for 35.6%, _C. sapidus_ 13.6%, _L. polyphemus_ 13.4%, _P. gibbesii_ 8.4%, _L. brevis_ 7.5% and _S. empusa_ 6.3%.

Table 7.1 presents seasonal abundances of these dominant species according to the six hour sampling intervals. Also presented are total numbers of invertebrates collected during each season and the estimated number of invertebrates impinged per day within each season. Higher numbers of invertebrates were collected during the summer (July - September) and the winters (January - March) of 1976 and 1977. Lower numbers were collected during the spring (April - June) and fall months (October - December). The rates of impingement followed this same pattern, with the higher rates occurring in the summer and winters and the lower rates during the spring and fall.

The relative abundance of impinged species varied seasonally. _P. duorarum_ accounted for almost 76% of the invertebrates collected during the summer, while no individuals of this species were collected during the spring. During the winter months (January - March) of 1976, the samples were dominated by _P. duorarum_ (37.9%), _C. sapidus_ (18.0%) and _L. polyphemus_ (22.5%). During the winter of 1977, samples were dominated by

Table 7.1. List of most abundant invertebrate species impinged at Big Bend (one unit) between January, 1976 - March, 1977. (1 = 0001-0600 hrs., 2 = 0601-1200 hrs., 3 = 1201-1800 hrs., and 4 = 1801-2400 hrs).

	Jan - March '76				April - June				July - Sept.				Oct. - Dec.				Jan. - Mar. '77				Total
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Penaeus duorarum Pink shrimp	271	90	312	256	0	0	0	0	362	305	491	763	60	52	22	56	80	75	20	114	3329
Callinectes sapidus Blue crab	210	56	61	115	5	20	1	8	1	0	0	0	49	37	78	17	216	164	54	185	1277
Limulus polyphemus Horseshoe crab	215	54	180	103	26	55	21	31	38	33	8	14	35	35	10	29	90	111	67	103	1258
Portunus gibbesii Portunid crab	68	12	23	40	0	0	0	0	3	9	10	8	56	76	96	39	98	128	31	89	786
Lolliguncula brevis Brief squid	25	6	17	28	45	53	20	55	110	92	24	93	25	8	9	41	26	10	11	6	704
Squilla empusa Mantis shrimp	36	17	10	54	2	3	6	4	0	0	0	0	19	51	82	4	152	51	50	57	598
Total Invertebrates	2454				1064				2529				1293				2024				
Number of sampling days	6				7				6				7				5				
Estimated invertebrates impinged per day (# collected ÷ # of sampling days)	409.0				152				421.5				184.7				408.4				

P. duorarum (14.2%), *C. sapidus* (30.5%), *L. polyphemus* (18.2%), *P. gibbesii* (16.9%) and *S. empusa* (15.2%). During the spring, the horseshoe crab *L. polyphemus* (13.6%) and the squid *L. brevis* (16.3%) dominated the samples collected. Dominance within the samples collected in the fall of 1976 was evenly distributed between all six of the cited dominant species.

Effects of Temperature

Figure 7.3 presents graphically the total number of invertebrates collected on each sampling date and the average water temperature at the intake at the time of sampling. Generally, peaks in invertebrate impingement occurred at temperature extremes while depressions in impingement occurred during moderate temperatures. This follows from Table 7.1, which demonstrated that impingement was more pronounced during the summer and winter months and depressed during the spring and fall months. It was not possible to discern whether these peaks in impingement were the result of temperature stress on the organisms impinged or simply a result of increased abundance of the organisms in the Big Bend area at these times of year (summer, 1976 and the winters of 1976 and 1977).

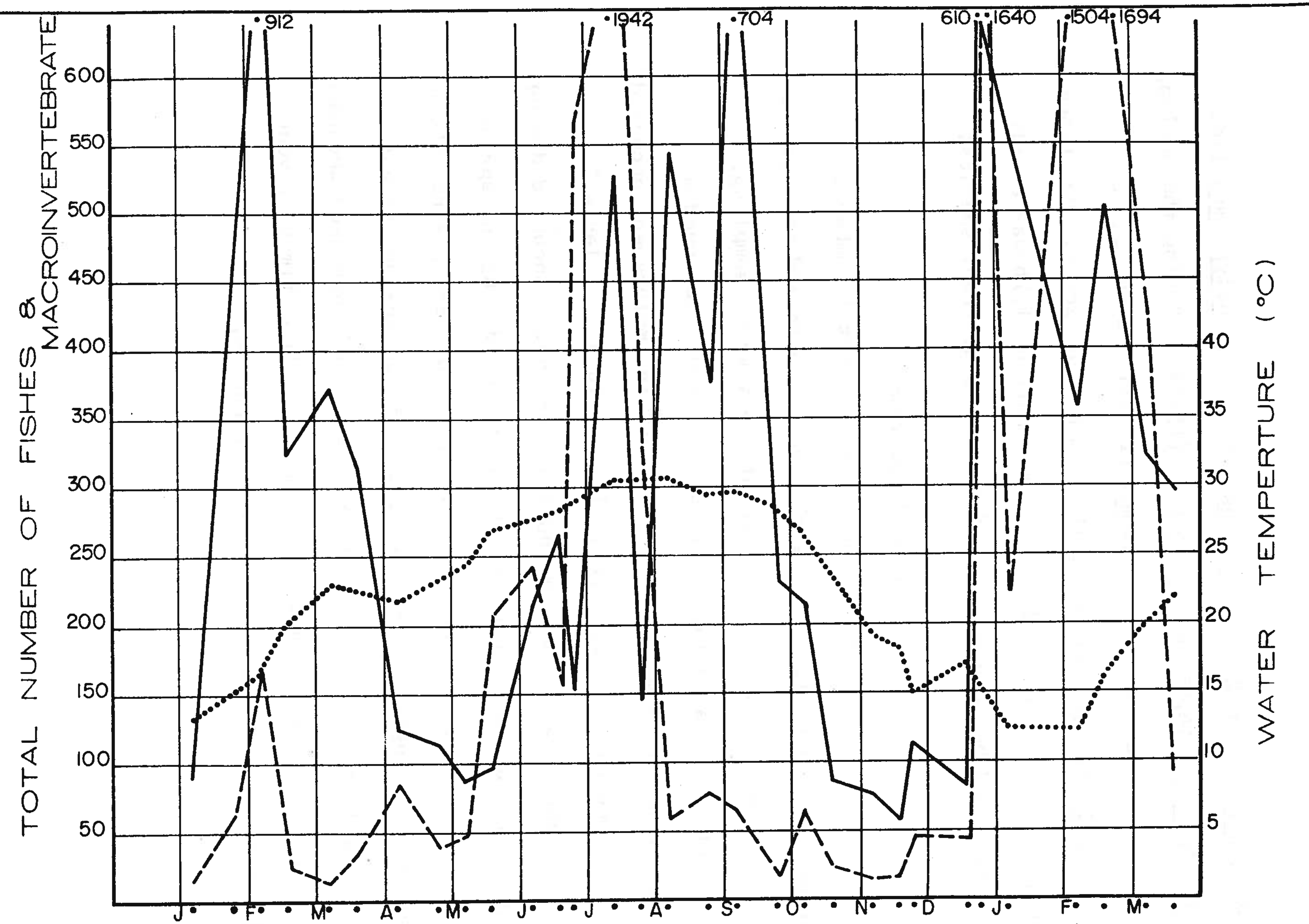

Figure 7. 3. Total number of fish and macroinvertebrates that were impinged on one unit between January, 1976 and March, 1977. Water temperature values represent the average temperature at the intake when samples were collected.

Day Versus Night Impingement

A seasonal breakdown of the numbers of invertebrates impinged at night and during the day is presented in Appendix 7.A. More invertebrates were impinged during the night hours (1800-2400 hours). However, a statistical analysis (t-test) of the data showed that there was no significant difference ($\alpha = 0.05$) between day and night impingement.

Effects of Lighting

In an attempt to evaluate the effects of lighting at the intake structure, five nights were sampled with lights on and another five nights were sampled with lights off. The results of this sampling are presented in Appendix 7.B. Although more invertebrates were collected during the sampling periods with the lights on, the difference was not significant ($\alpha = 0.05$).

Size Classes

Limited size class data was generated for all invertebrates impinged at Big Bend. This data is presented for each of the six dominant species in the following section.

Dominant Species

Penaeus duorarum

The decapod, *Penaeus duorarum* (pink shrimp) was the dominant invertebrate impinged comprising 35.4% of the total invertebrate catch. A total of 3,329 individuals (107.4 organisms/24 hours) were impinged over the 15 sampling months. Greatest impingement occurred during February, June, July and August, 1976 and the least during April and May. Approximately 68% of the total impingement of this species occurred at night. Utilizing operational data, it is estimated that 25,773 individuals would have been impinged during the 15 months of 1976 and 1977 (based on an impingement rate of 107.4 per day over the eight months of noted abundance).

Cummings (1961) stated that the greatest spawning of pink shrimp in Florida waters occurs from April - July, although ripe and nearly ripe females were found at other times of the year. Eldred, Ingle, Woodburn, Hutton and Jones (1961) found that shrimp which were spawned in late March or April could reach 45 to 65 mm by July and that those spawned in May could reach 25 to 35 mm by July.

Individuals impinged during the months of July, August and September were probably spawned in late March or April. Sampling indicated that an extended spawning season or multiple spawning seasons do occur. Total length of impinged shrimp ranged from 19 to 156 mm. Figure 7.4 presents monthly size class data for P. duorarum.

From the extrapolated number of shrimp impinged over the 15 month study period it was estimated that approximately 920

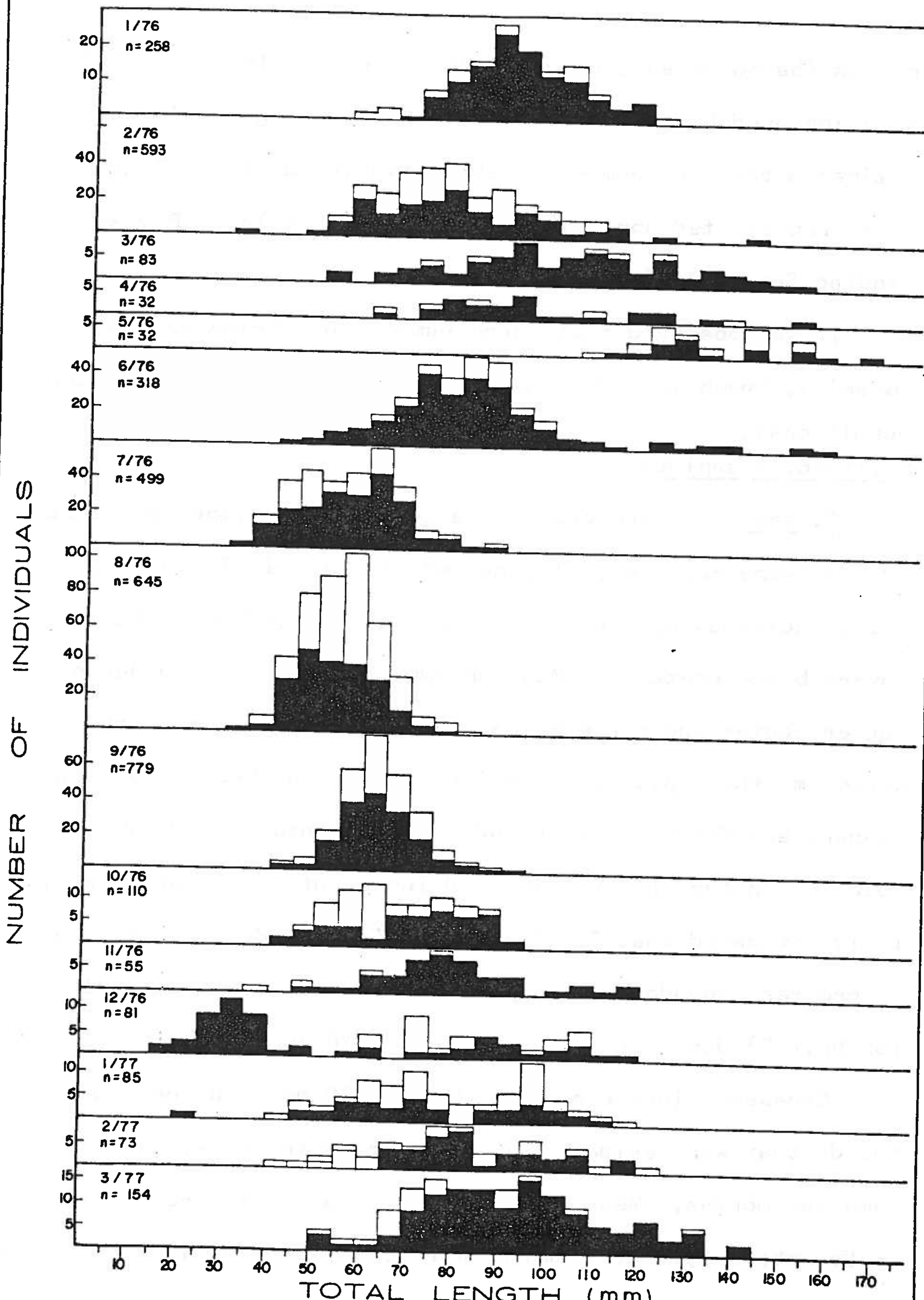

Figure 7.4. Length distribution of Penaeus duorarum (Pink shrimp) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

pounds (based on an average of 28 shrimp per lb) of shrimp were impinged by one unit. Based on these figures it was estimated that the number of shrimp impinged at Big Bend (one unit) represented approximately 0.23% of the Tampa Bay shrimp landing from 1975 (USDC, 1975).

It was observed that large numbers of shrimp were alive in the sluicing trough and in the samples (and survived 24 hours under experimental conditions).

Callinectes sapidus

C. sapidus (blue crab) is a commercially important species in the Tampa Bay area. Impingement totaled 1,277 individuals (41.2 individuals/24 hours) and was the second most abundant invertebrate captured. Maximum impingement occurred during cooler months and minimum impingement occurred during the warmer months. Blue crab impingement during December, 1976, January and February, 1976 and 1977 accounted for 92.4% of the total catch for this species. Using plant operational data, it is estimated that 7,414 individuals (based on six months of greatest abundance) would have been impinged by Unit 1 (or Unit 2) during the 15 months of 1976 and 1977.

Carapace width ranged from 9 to 170 mm. The only growth trends that were evident occurred during the final four sampling months. Mean carapace width increased from 40 mm in December, 1976 to 76 mm by March, 1977. Monthly size class data for C. sapidus is presented in Figure 7.5. A large number of individuals were alive in samples and observed alive in the sluicing trough. Based on commercial catch statistics provided by the National Marine Fisheries Service, it was estimated that approximately 0.7% of the commercial blue crab catch was impinged by 1 unit in 1976.

Limulus polyphemus

Limulus polyphemus (horseshoe crab) was the third most abundant invertebrate impinged (1,258 individuals). Impingement was greatest during the cooler months and least during the warmer months. Impingement during February, 1976 and 1977 accounted for 61.4% of the total catch for this species which may have been due to an inshore spawning migration. After spawning, L. polyphemus spends the rest of the summer feeding in shallow water until the onset of winter when they move back into the deeper water (Lewis, 1975). Little variation in impingement was noted between day and night, or between males and females. Approximately 7,304 individuals (based on 6 months of noted abundance) would have been impinged by Unit 1 (or Unit 2) throughout the study period.

L. polyphemus

All individuals (except 5) were alive at the time of sample collection.

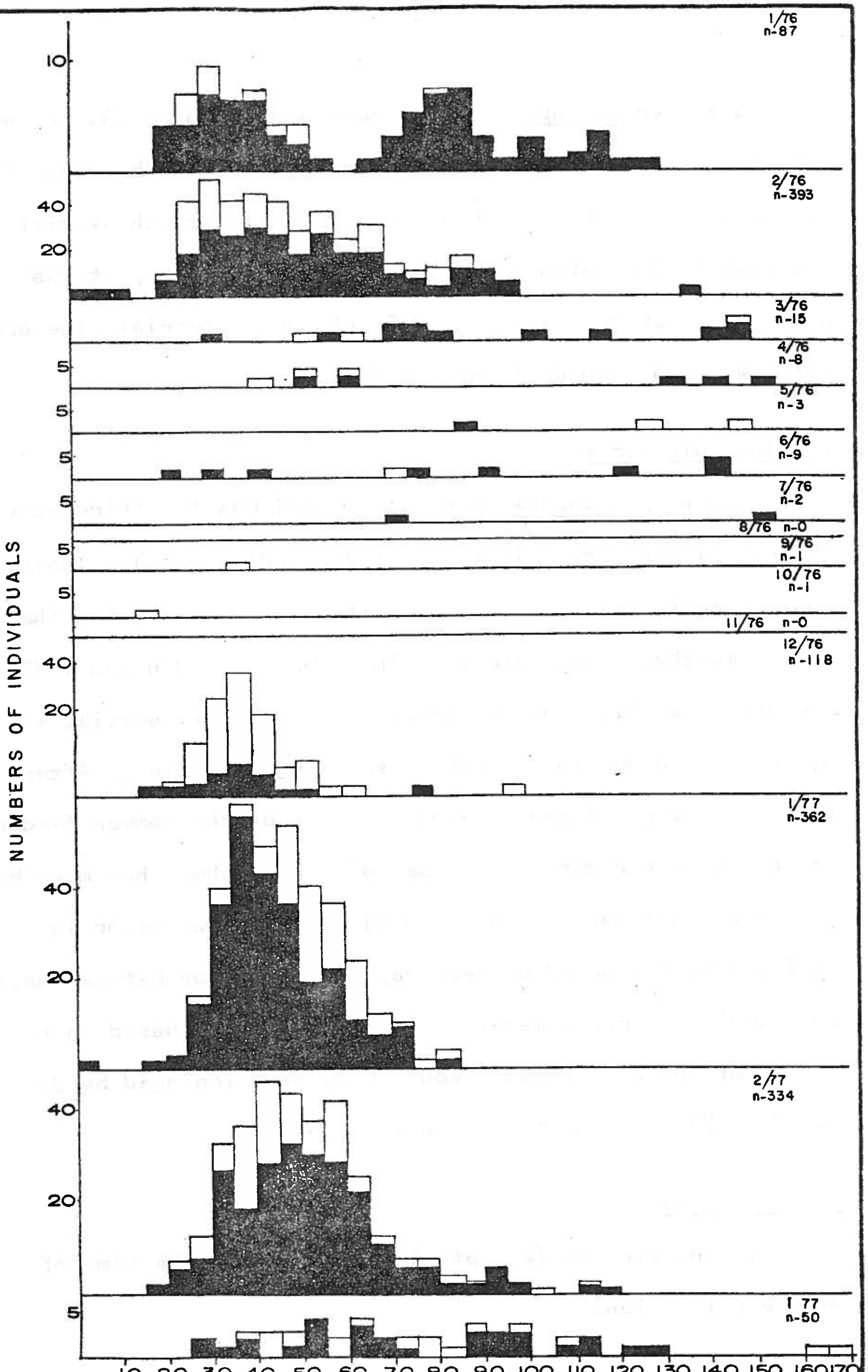

Figure 7.5. Standard length distribution of Callinectes sapidus (Blue crab) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement...

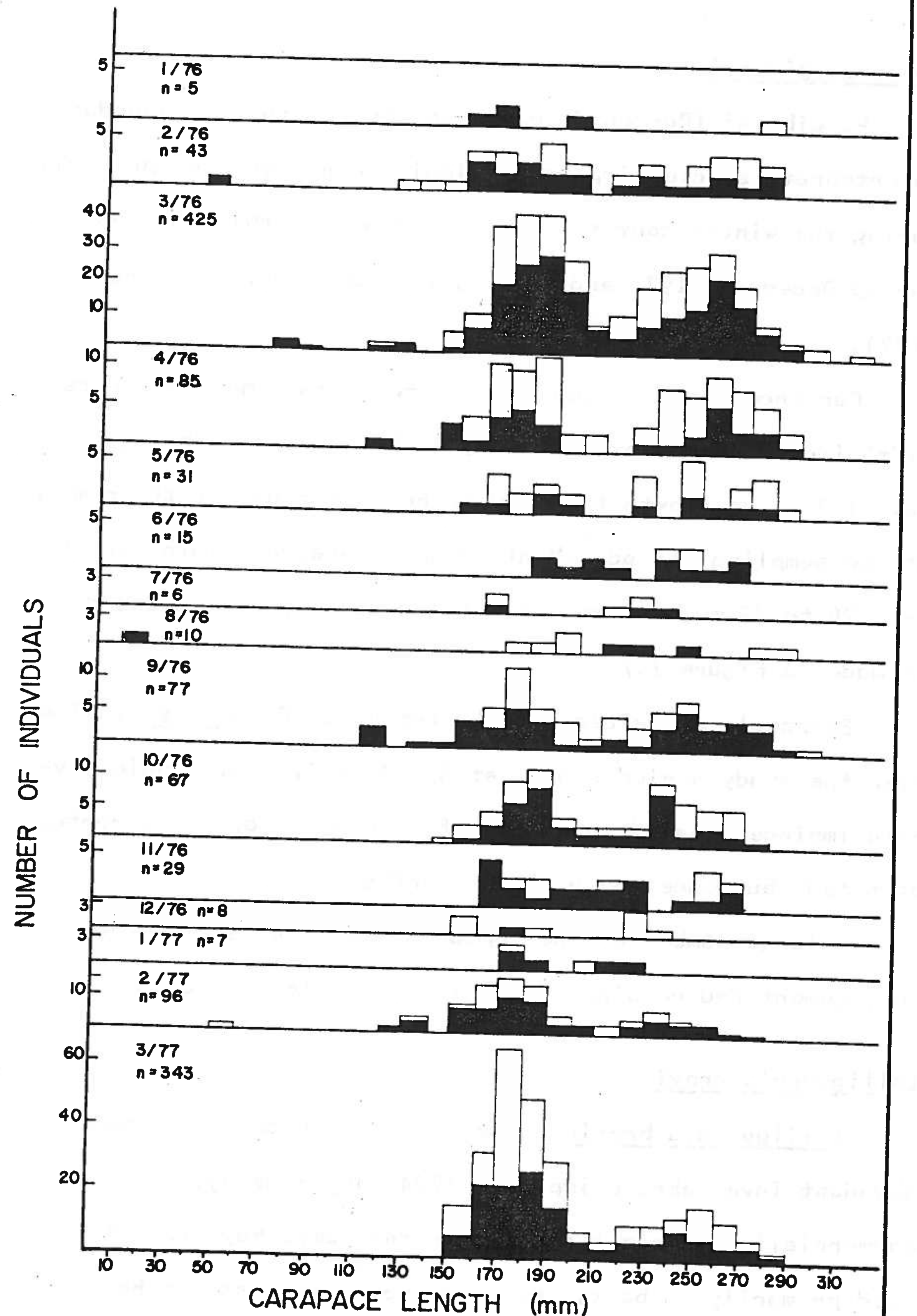

Figure 7.6. Standard length distribution of Limulus polyphemus (Horseshoe crab) from January, 1976 through March, 1977. Each bar represents a 10mm size class. Dark areas represent night impingement.

Portunus gibbesi

P. gibbesi (Portunid crab) was the fourth most abundant invertebrate species impinged. Impingement occurred primarily during the winter months (81.1% of total for this species during December, 1976 and January and February, 1976 and 1977).

Carapace width ranged from 10 to 68 mm. Mean carapace width increased approximately 13 mm from January through May, 1976. No growth trends were noted throughout the remainder of the sampling period. Monthly mean carapace width ranged from 29 to 45 mm. A presentation of monthly size class data is made in Figure 7.7.

Extrapolated values for the number of *P. gibbesi* impinged over the study period show that 4,564 individuals would have been impinged (based on a rate of 25 per day over six months of noted abundance) over the 15 months.

A large number of the captured individuals survived impingement and remained alive in the sluicing trough.

Lolliguncula brevis

Lolliguncula brevis (brief squid) was the fifth most abundant invertebrate impinged (704 individuals). This is a commercially important species in the Tampa Bay area, being used primarily as bait. Maximum impingement at Big Bend

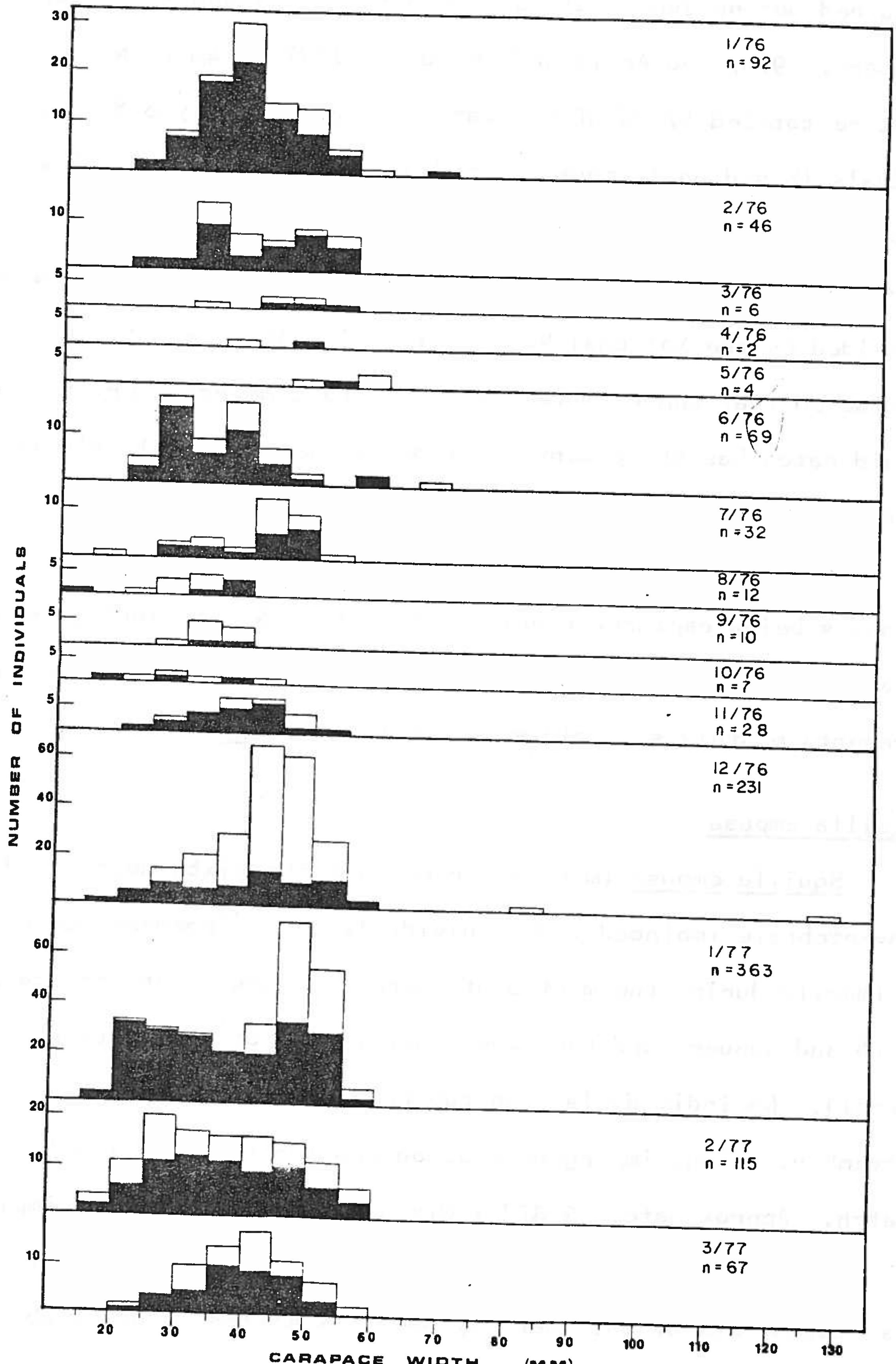

Figure 7.7. Standard length distribution of <u>Portunus gibbesi</u> (Portunid crab) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

occurred during June, July and August (51.9%) and least during January, 1976, and April and February, 1977 (5.4%). Night capture totaled 67.9% of the catch. Approximately 8289 individuals (based on 12 months noted abundance) would have been impinged by Unit 1 (or Unit 2) during operational hours throughout the study period. Utilizing commercial catch data provided by the National Marine Fisheries Service, it was estimated that approximately 5.1% of the commercial brief squid catch has the potential of being impinged by 1 unit in a full operational year.

Pen length ranged from 16 to 127 mm with several size classes being captured nearly year round. No distinct growth trends were noted over the entire sampling period. Figure 7.8 presents monthly size class data for L. brevis.

Squilla empusa

Squilla empusa (mantis shrimp) was the sixth most abundant invertebrate impinged (598 individuals). Impingement occurred primarily during the months of December, January and February, 1976 and January and February, 1977 (94.8% of the species total). No individuals were captured from July through November. Night impingement accounted for 63.5% of the total catch. Approximately 3,472 individuals would have been impinged by Unit 1 (or Unit 2) during operational hours in 1976 (at an estimated rate of 19.3 per day over six months of noted abundance).

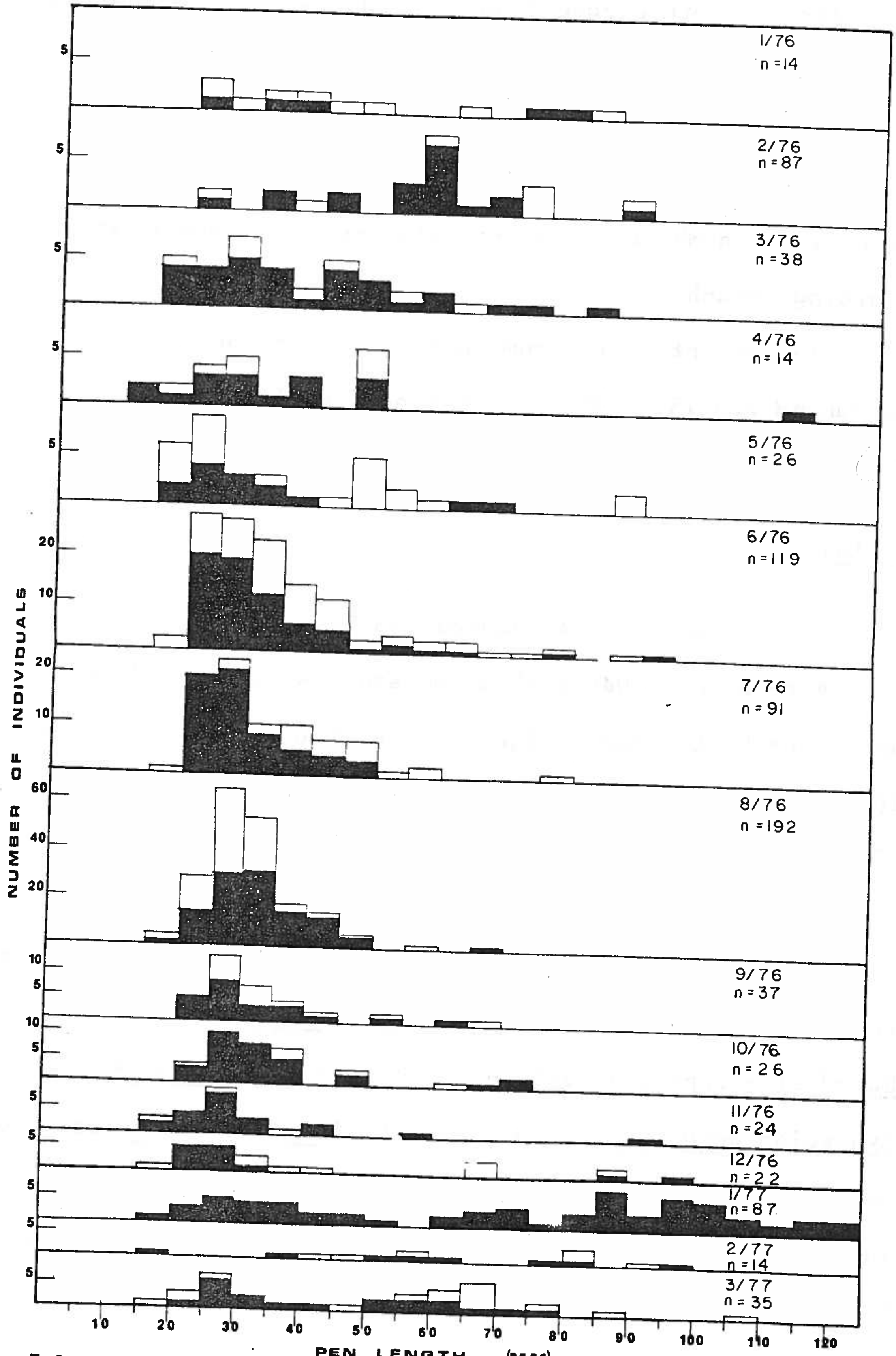

Figure 7.8. Pen length distribution of Lolliguncula brevis (Bried squid) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

Total length ranged from 65 to 150 mm. No discernable growth trends were evident. Monthly size class data is presented in Figure 7.9.

Mantis shrimp appeared capable of surviving impingement since large numbers of individuals were observed alive in the sluicing trough.

Impingement of the remaining 21 invertebrates species accounted for 15.2% of the total number of invertebrates and 1.1% of the total invertebrate biomass.

Fishes

Relative Abundance and Seasonality

A total of 9,946 fishes (60 species) were impinged on Unit 1 or Unit 2 during 744 sampling hours between January, 1976 and March, 1977. Based on this information, an average of 13.4 fish were impinged on one unit per hour of sampling time.

Table 7.2 outlines the relative abundance of the six most commonly impinged fishes (*Anchoa mitchilli*, bay anchovy; *Bairdiella chrysura*, silver perch; *Lagodon rhomboides*, pinfish; *Cynoscion arenarius*, sand seatrout; *Prionotus scitulus*, leopard searobin; and *Chloroscombrus chrysurus*, Atlantic bumper). These six species constituted 85.6% of the total number of fishes that were impinged during sampling hours.

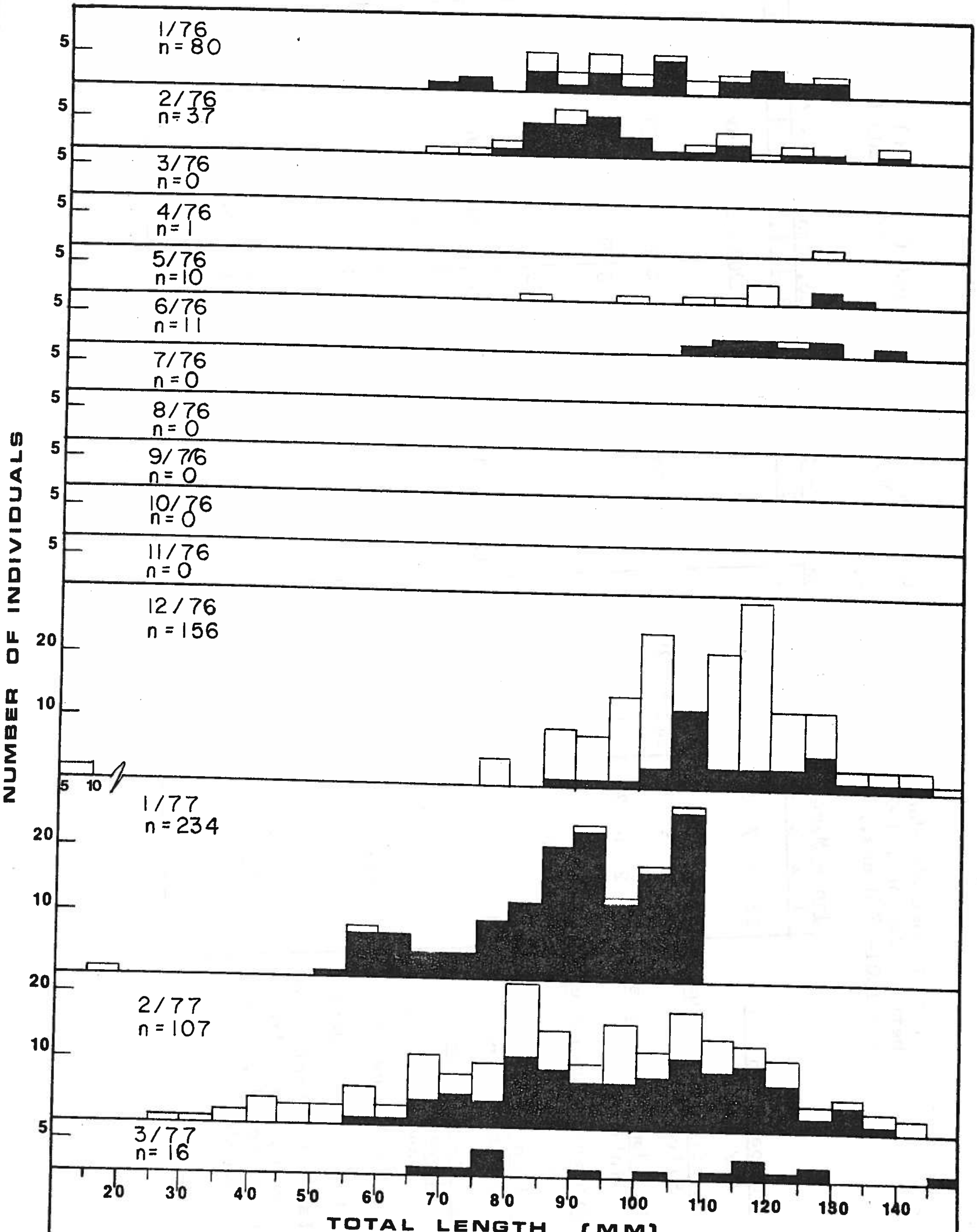

Figure 7. 9. Total length distribution of <u>Squilla empusa</u> (Mantis shrimp) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

Table 7.2. List of most abundant vertebrate species impinged at Big Bend (one Unit) between January, 1976 - March, 1977. (1 = 0001-0600 hrs., 2 = 0601-1200 hrs., 3 = 1201-1800 hrs., 4 = 1801-2400 hrs.)

	Jan - March '76				April - June				July - Sept.				Oct- Dec.				Jan. - Mar '77				
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	Total
<u>Anchoa</u> <u>mitchilli</u> Bay anchovy	22	6	7	5	24	13	14	14	7	8	5	13	252	179	292	226	982	1171	299	506	4045
<u>Bairdiella</u> <u>chrysura</u> Silver perch	17	1	5	4	142	84	39	236	1184	251	160	499	41	80	3	32	107	57	53	33	3028
<u>Lagodon</u> <u>rhomboides</u> Pinfish	13	2	6	3	14	65	40	48	4	1	40	45	0	0	1	3	58	97	19	17	476
<u>Cynoscion</u> <u>arenarius</u> Sand seatrout	8	1	6	0	4	53	2	29	31	16	1	5	31	41	12	22	66	10	3	2	343
<u>Prionotus</u> <u>scitulus</u> Leopard searobin	14	1	6	6	15	29	4	21	10	1	0	1	10	7	47	7	98	24	12	6	319
<u>Chloroscombrus</u> <u>chrysurus</u> Atlantic bumper	0	0	0	0	0	0	0	3	10	31	19	20	52	67	20	31	33	9	0	7	302
Total vertebrates	315				1339				2504				1852				3936				
No. of Sampling Days	6				7				6				7				5				
Estimated vertebrates impinged per day (#Collected ÷ #days sampled)	52.5				191.3				417.3				264.6				787.2				

(31)

Most of the fishes (59.2%) were impinged during the night sampling hours (0001 to 0600 and 1800 to 2400 hours). However, a t-test indicated that there was not a significant difference between the number of fishes impinged during the day and the number impinged at night ($\alpha = 0.05$).

Seasonal variations in impingement were evident (Appendix 7.A). The summer (1976) and winter (1977) months accounted for the highest rates of impingement. (Appendix 7.C presents a list of the fishes and macroinvertebrates that were impinged during this study, and the season in which they were impinged.)

An average of 52.5 fish per sampling day were collected between January and March, 1976. This rate increased each quarter of sampling until a peak impingement rate of 417.3 fish per sampling day occurred between July and September, 1976. Another peak occurred between January and March, 1977 when the impingement rate rose to an average of 787.2 fish per sampling day.

Throughout the fifteen month sampling period, three species were seasonally abundant on the travelling screens. These three species were Sciaenops ocellata (red drum), which were abundant between January and March, 1976; Bairdiella chrysura (sand seatrout), which were abundant between April and September, 1976; and Anchoa mitchilli (bay anchovy) which peaked in abundance between October, 1976 and March, 1977.

Effects of Lighting

During sixty night sampling hours between January 24 and March 19, 1976 a total of 183 fishes were impinged on the travelling screens of Unit 1, when there was no lighting on this structure. This corresponds to an average impingement rate of 3.05 fishes per sampling hour.

Conversely, a total of 190 fishes (3.2/hour) were impinged on the screens of Unit 1 during sixty night sampling hours when normal lighting was in operation at this unit. While slightly fewer fishes were impinged when the lights were off, this difference was not significant (t-test; $\alpha = 0.05$). Appendix 7.B outlines the differences in abundance between lights on and lights off sampling.

Certain regulations concerning lighting procedures forced the premature termination of this phase of the study. While the data is inconclusive, it does suggest that the effects of lighting (e.g. attracting fish to the intake structure) on impingement were negligible.

Effects of Temperature

Figure 7.3 outlines the relative abundance of impinged organisms in relation to water temperature. Peak periods of abundance on the travelling screens appeared to correspond to high and low water temperatures recorded at the intake.

Whether this trend is coincidental (e.g. a large number of fish were present during these times and, therefore, more susceptible to impingement) or causative (e.g. extreme low or high temperatures may induce lethargy thereby increasing the probability of impingement) is not known.

Dominant Species

Anchoa mitchilli

The bay anchovy (*A. mitchilli*) was the most abundant fish impinged on the travelling screens. This species constituted 40.7% of the total number of vertebrates that were impinged during sampling hours. An average impingement rate of 5.4 individuals per hour (129.6/day) was determined for the 744 hours that were sampled.

Most of the specimens (96.6%) were collected between October, 1976 and March, 1977. The period between January and March, 1977 accounted for 73.1% of the individuals.

Of the 4,045 individuals that were collected, 50.7% were impinged at night.

Bay anchovies were abundant in the Big Bend area from October through December, 1976 (Comp, 1977), and in February and March, 1977 (see Chapter 8). Most of the anchovies captured by the screens were adults (average standard length was over 50 mm). This was probably due to mesh size selectivity of the screens, since juvenile bay anchovies were also abundant during the periods of high temperature (see Chapter 8), yet they were rarely found on the screens.

There are two possible explanations for the disparity in abundance that was noted in the catches for January through March, 1976 and for those made in January through March, 1977. Relatively few anchovies were collected on the screens in early 1976. This species was absent from the seine catches during this same period (Comp and Morris, 1976). It is possible that, for some reason, this species did not move into the shallow inshore waters during early 1976 as they did in early 1977. Accordingly, it is possible that the likelihood of impingement during early 1977 increased as a result of the presence of large numbers of individuals in the Big Bend area.

Another possibility is that sustained cold weather (and water) may have induced lethargy thus increasing the susceptibility of this fish to impingement.

Between the sampling periods from December 29, 1976 and February 8, 1977, water temperature at the intake ranged from 12.6°C to 15°C. However, anchovies have been captured in areas with low water temperatures (16°C, Comp, Chapter 8; 10.8°C, Springer and Woodburn, 1960; 7.9°C, Dahlber, 1972). That increased rates of impingement were due to cold water is speculation.

Extrapolating the data that was collected in 744 sampling hours, one unit would impinge approximately 47,627 individuals in one year (assuming that the unit was in operation every day).

This species is abundant in the Tampa Bay area (Chapter 8; Springer and Woodburn, 1960), so it is doubtful that the impingement rates that were determined for this species, signify a detrimental depletion of this species.

Monthly size class data for A. mitchilli is presented in Figure 7.10.

Bairdiella chrysura

The silver perch (Bairdiella chrysura) constituted 30.4% of the total number of fish that were impinged during sampling hours. The average impingement rate of this species was approximately 98 fish per day (35,770 individuals/year/unit).

Of the 3028 specimens that were collected, 75.8% of the individuals were impinged at night. Most of the individuals (85.7%) were impinged between April and September, 1976. Peak catches occurred in July.

Standard length distribution of this species is presented in Figure 7.11. Growth patterns are difficult to discern.

Eggs of this species were found in the Big Bend area in February and March, 1976 (T. D. Phillips, pers. comm.). This indicates a late winter - spring spawning season. This agrees with the findings of Springer and Woodburn (1960). Based on

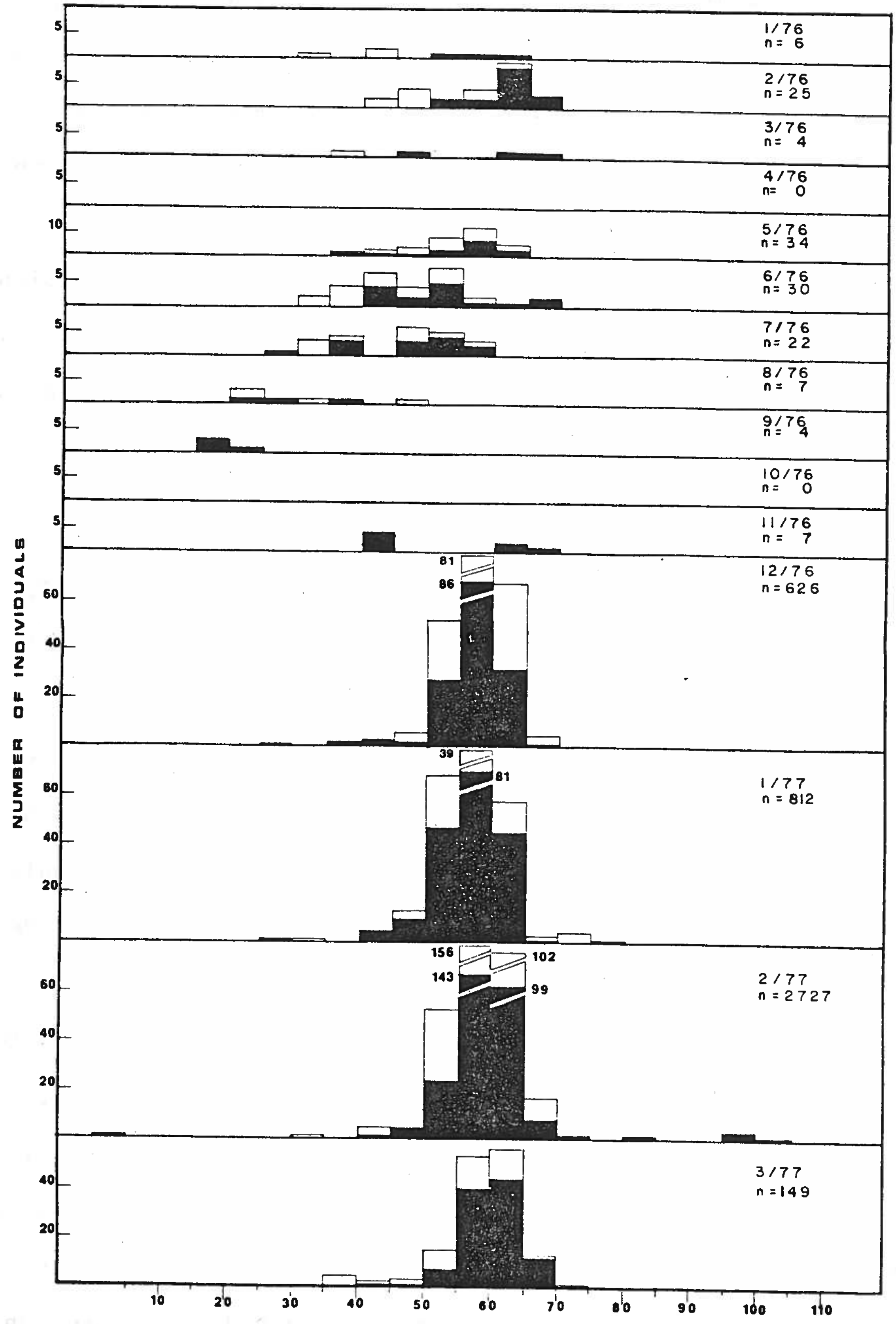

Figure 7.10. Standard length distribution of <u>Anchoa mitchilli</u> (Bay anchovy) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

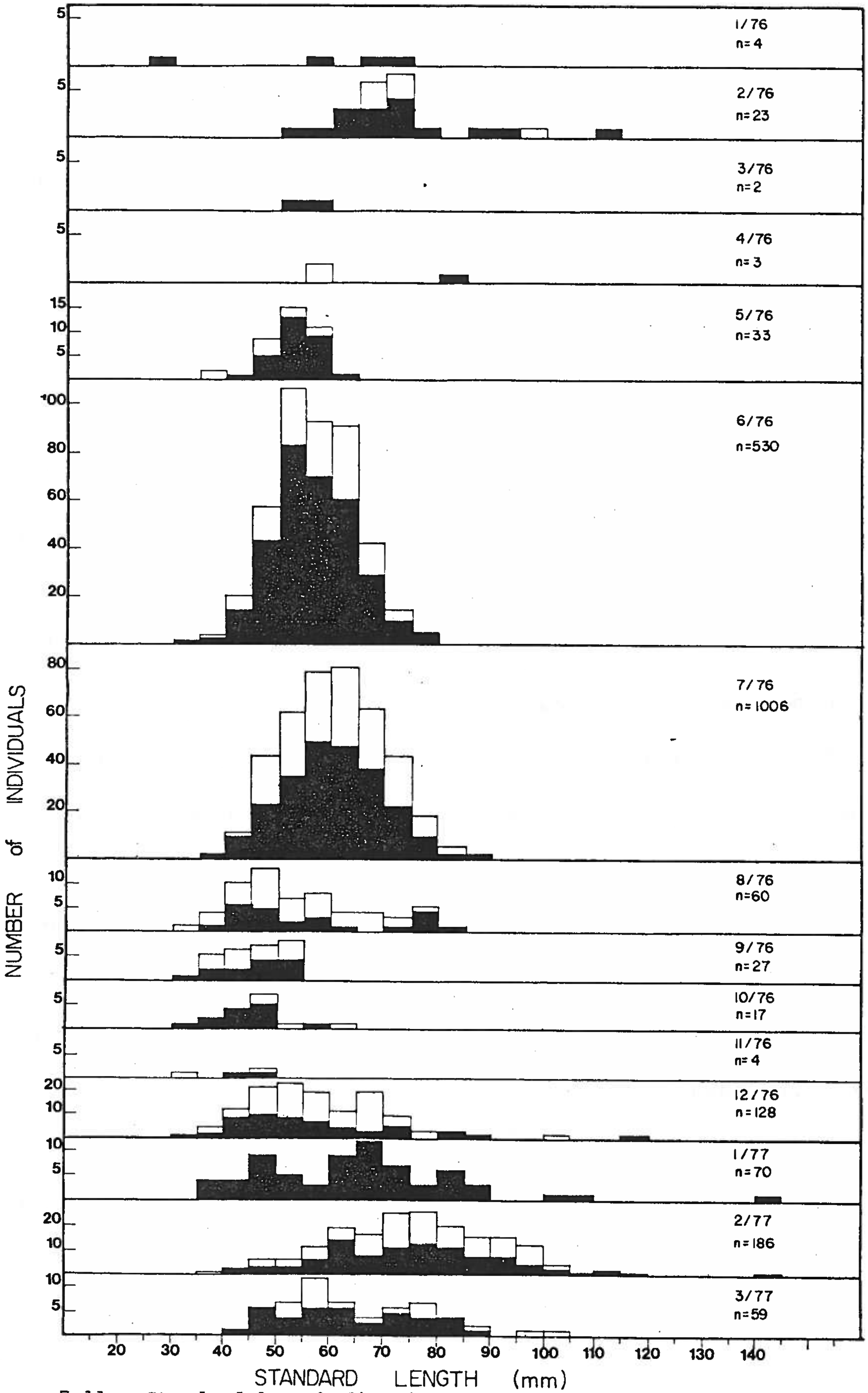

Figure 7.11. Standard length distribution of Bairdiella chrysura (Silver perch) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

the data collected from the travelling screens, it is conceivable that the adults move to offshore areas in the bay to spawn. Upon cessation of spawning periods, the adults migrate back to the shallower areas. This migration apparently occurs during the summer and fall months. Merely by their relative abundance in this area during the summer and fall, this species becomes more susceptible to impingement.

Lagodon rhomboides

Pinfish (Lagodon rhomboides) accounted for 4.8% of the total number of fishes that were impinged within 744 sampling hours. Based on the actual number of pinfish that were collected, an average of 15.4 fish per day were impinged (5621 individuals/year/unit).

Of the 476 pinfish that were collected on the screens during sampling hours, 56.9% were impinged during the day.

Pinfish were most frequently impinged between January and March, 1977. Fewest individuals were impinged between October and December, 1976. Since spawning apparently occurs in the Gulf during late fall and early winter (Springer and Woodburn, 1960) this species would not be expected to be abundant in inshore areas during this time. Pinfish were noticeably absent from the seine catches during this period (Comp, 1977), which supports the belief that much of the population had migrated to the Gulf, or offshore regions.

Pinfish have been collected in water with temperatures as low as 10.0°C (Springer and Woodburn, 1960). It is not known if sustained low temperatures in the discharge area increased the susceptibility of impingement for this species during early 1977. Again, it is possible that the normal seasonal abundance may have contributed more to impingement than the effects of temperature.

Figure 7.12 presents monthly standard length distributions of *L. rhomboides*.

Cynoscion arenarius

The sand seatrout (*Cynoscion arenarius*) was the fourth most abundant fish impinged during sampling hours. This species constituted 3.4% of the total fish catch. Based on this data, an average of 11.2 sand seatrout were impinged per day.

Of the 343 individuals that were impinged, 57.7% were impinged during the night. Peak impingement occurred between April and June, 1976 and again between October and December, 1976.

Based on actual data, approximately 4,088 individuals would be impinged by one unit during the year.

Larvae of this species are common in the Big Bend area throughout the summer months (Phillips, 1977). Reid (1954) captured sexually mature adults of this species in the spring. This indicates a spring - summer breeding season.

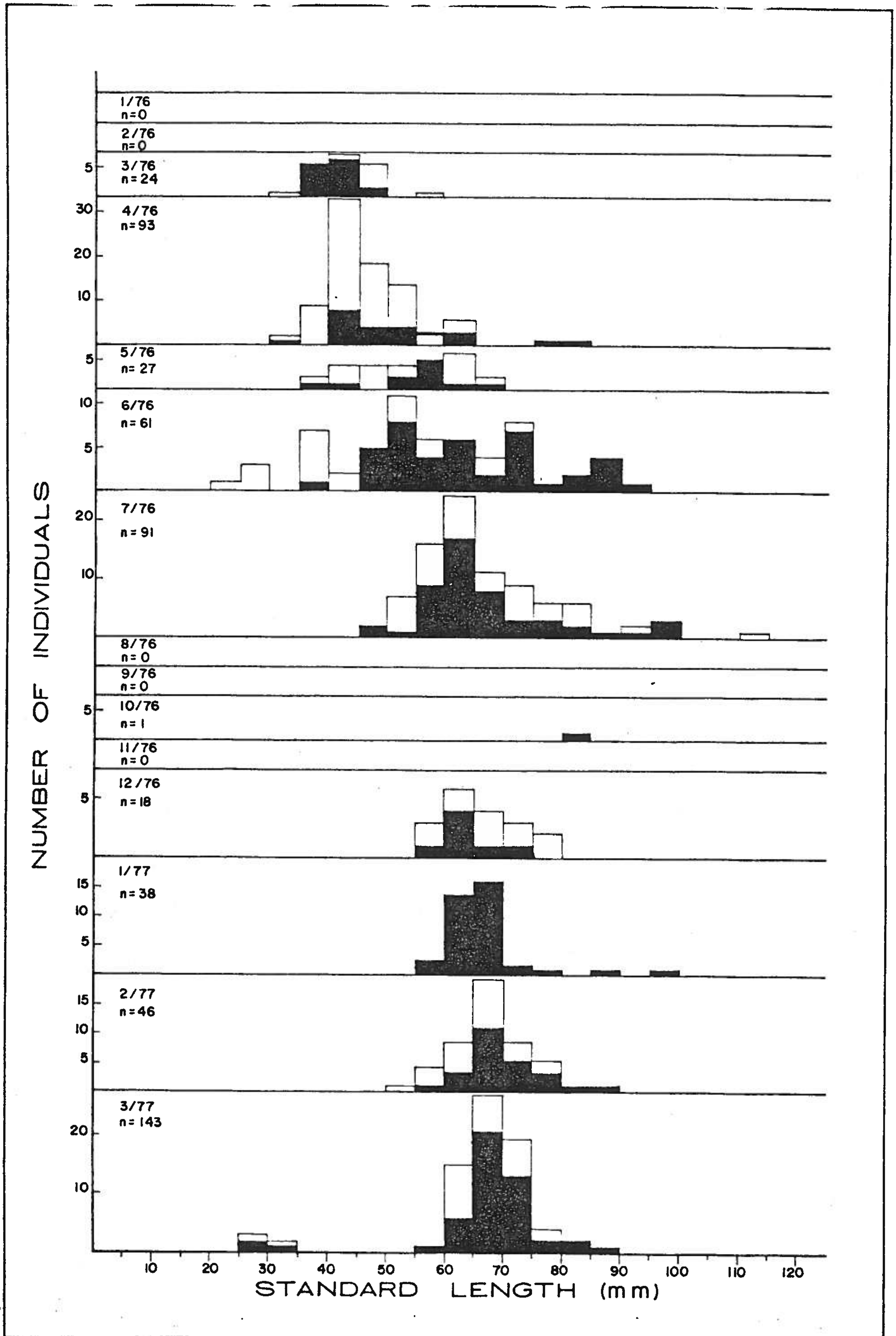

Figure 7.12 Standard length distribution of Lagodon rhomboides (Pinfish) from January, 1976 through March, 1977. Each bar represents a 5 mm size class. Dark areas represent night impingement.

Small specimens (SL $<$ 35 mm) were impinged in May, June, July and September, 1976. These findings also indicate an extended breeding season for this species.

A length distribution outline for C. arenarius is presented in Figure 7.13. Average standard length appears to steadily increase from October, 1976 through March, 1977.

IMPACT ASSESSMENT

To accurately assess the impact of impingement on fish and macroinvertebrate communities, the standing crop and/or productivity potential of those communities should be enumerated. Unfortunately, this is a difficult, if not impossible task in estuarine areas since these regions support such dynamic communities. Constant migrations to and from these areas cause significant changes in seasonal abundance and species composition.

Assessment of impact in these regions is limited to comparing impingement data with other methods of sample collection in the same area (e.g. seines and trawls); known seasonal patterns of abundance; other impingement studies; and commercial catch data.

When compared to other studies (Mathur, Heisey and Magnusson, 1977; Edwards, Hunt, Milla, and Sevic, 1975; Landry

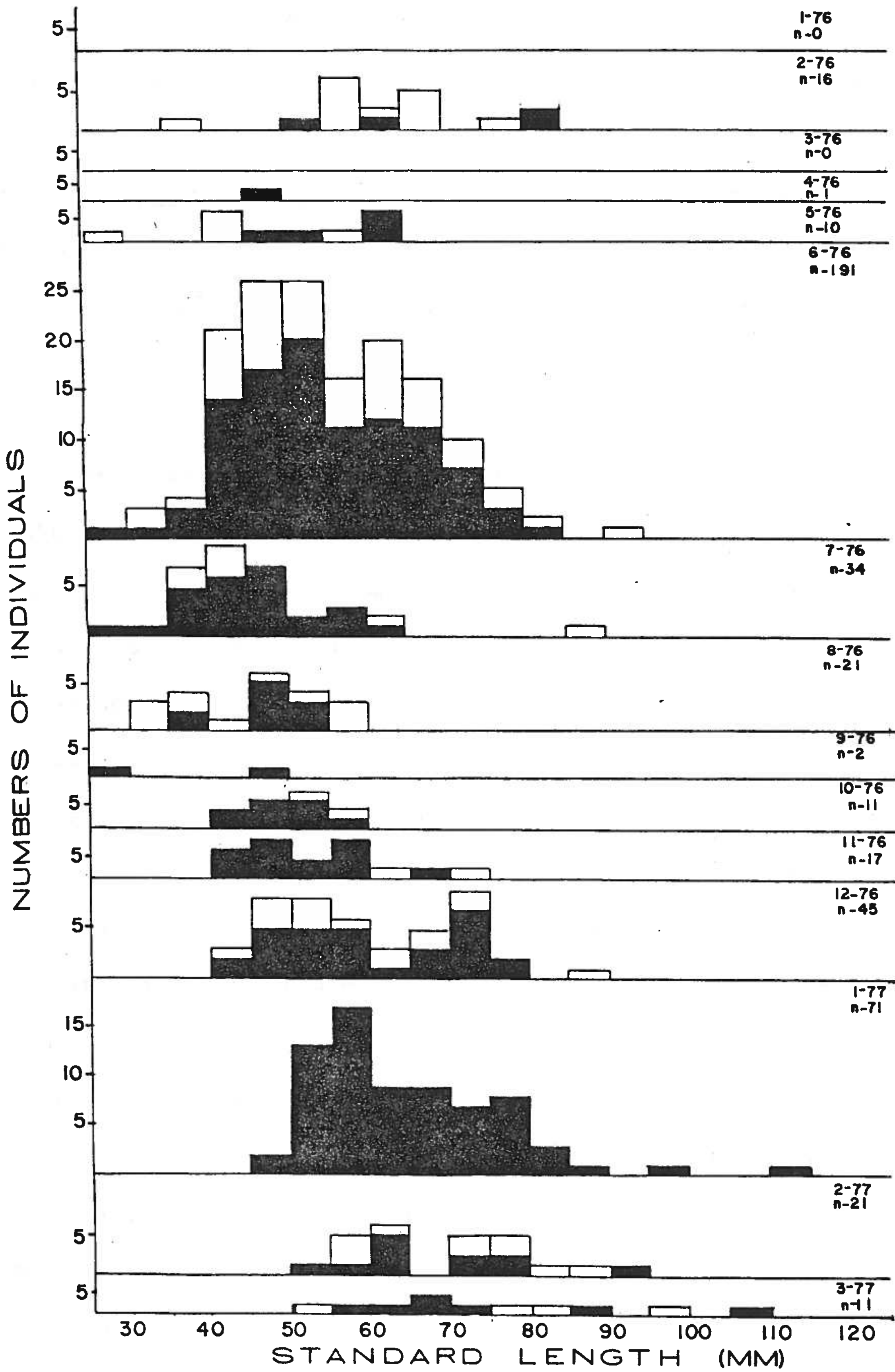

Figure 7.13. Standard length distribution of Cynoscion arenarius (sand seatrout) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

and Strawn, 1974) the impingement rate at Big Bend is rather low. This is due in part to the location of the intake structure. Since the travelling screens are removed from a major source of water (see Figure 7.2) most fishes and invertebrates would not be subjected to impingement. The current (flow) due to the intake mechanism is negligible at the west end of the intake canal. Therefore, only those individuals which enter the canal voluntarily would be susceptible to impingement.

Coal barges dock at the west end of the intake canal. As these barges approach the dock, there is a remote possibility that the barges will "herd" schools of fishes into the canal. Subjective visual observations have not substantiated this occurrence. However, we are cognizant of the possibility that herding may occur.

Most increases and/or decreases in impingement rates appear to correspond to seasonal changes in abundance. Seasonality has also been a factor which influenced impingement rates at other sites (Mathus, et al., 1977; Edwards, et al., 1975; Landry and Strawn, 1974; Grimes, 1971).

The time of day (or night) can also influence impingement rates (Appendix 7.D). During this study, more individuals were impinged during the night, especially between 0001 and 0600 hours, but this was not statistically significant.

Impingement at Big Bend does not appear to be significantly depleting the commercial stock in this area. Based on the 1976 commerical catch for Hillsborough County (B. Gassinger, National Marine Fisheries Service, pers. comm.) one unit may have impinged approximately 0.23% of the commercial pink shrimp catch and 0.7% of the commercial blue crab catch. Extrapolated impingement data for one year indicated that one unit has the potential of impinging approximately 5.1% of the commercial catch of brief squid (L. brevis). Since rates of impingement vary with the seasons, these estimates are probably exaggerated.

Based on the data that was collected during 7 4 sampling hours between January, 1976 and March, 1977, it does not appear that impingement at Big Bend is significantly depleting the commercial fish and macroinvertebrate populations in this area.

SUMMARY AND CONCLUSIONS

1. A total of 9,382 macroinvertebrates (27 species) were impinged on either Unit 1 or Unit 2 during 744 sampling hours.

2. The average rate of impingement for Unit 1 was 302.6 invertebrates per day.

3. Pink shrimp (*Penaeus duorarum*), blue crabs (*Callinectes sapidus*), horseshoe crabs (*Limulus polyphemus*), portunid crabs (*Portunus gibbesii*), brief squid (*Lolliguncula brevis*), and mantis shrimp (*Squilla empusa*) constituted 84.8% of the total number of invertebrates that were impinged.

4. The pink shrimp (*P. duorarum*) constituted 35.6% of the total invertebrate catch.

5. The highest number of invertebrates were impinged during summer and winter, the periods of temperature extremes.

6. There was no significant difference ($\alpha = .05$) in the number of invertebrates impinged when the intake structure lights were off and then when they were on.

7. A total of 9946 fishes (60 species) were impinged on Unit 1 or Unit 2 during 744 sampling hours between January, 1976 and March, 1977.

8. The average rate of impingement was 320.8 fishes per day for one unit.

9. Bay anchovies (*Anchoa mitchilli*), silver perch (*Bairdiella chrysura*), pinfish (*Lagodon rhomboides*), sand seatrout, (*Cynoscion arenarius*), leopard searobin (*Prinotus scitilus*), and Atlantic bumper (*Chloroscombrus chrysurus*) constituted 85.6% of the total number of fishes that were impinged.

10. Most of the fishes (59.2%) were impinged at night.

11. The summer and winter months accounted for the highest rates of impingement.

12. Lighting on the intake structure did not appear to significantly increase the impingement rate for fishes.

13. Rates of impingement appear to be dependent on seasonal variations in abundance.

14. Impingement at Big Bend does not appear to be significantly depleting the commercial fish or invertebrate stock in this area.

LITERATURE CITED

Benda, R. S. 1976. Impingement studies at 16 plants on the Great Lakes and various rivers in Michigan. A paper presented at the Third National Workshop on Entrainment and Impingement, New York, New York.

Bernhard, H. P., and B. Latvaites. 1976. Impingement studies at the Quad Cities Nuclear Station. A paper presented at the Third National Workshop on Entrainment and Impingement, New York, New York.

Clark, J., and W. Brownell. 1973. Electric power plants in the coastal zone, Environmental Issues. American Littoral Society. Publ. 7. 144 p.

Comp, G. S. 1977. Fish and macroinvertebrate distribution as determined by seine and trawl catches, Chapter 8. In Tampa Electric Company, Twenty-ninth quarterly report on the Big Bend thermal and ecological surveys. Contains twenty-sixth quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 666 p.

Comp, G. S., and C. A. Morris. 1976. Macroinvertebrates and fish as sampled by trawls and seines, Chapter 8. In Tampa Electric Company, Twenty-sixth quarterly report on the Big Bend thermal and ecological surveys. Contains twenty-third quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 469 p.

Cummings, W. C. 1961. Maturation and spawning of the pink shrimp *Penaeus duorarum* Burkenroad. Trans. Amer. Fish. Soc. 90(4):462-468.

Dahlberg, M. D. 1972. An ecological study of Georgia coastal fishes. Fish. Bull. 70(2):323-353.

Edwards, T. J., W. H. Hunt, L. E. Miller, and J. J. Sevic. 1975. An evaluation of the impingement of fishes at four Duke Power Company Steam Generating Facilities. In G. W. Esch and R. W. McFarlane, eds. Thermal Ecology II. Proceedings of a symposium held at Augusta, Georgia. April 2-5, 1975.

Eldred, B., R. M. Ingle, K. D. Woodburn, R. F. Hutton, and H. Jones. 1961. Biological observations on the commercial shrimp Penaeus duorarum Burkenroad, in Florida waters. Fla. St. Bd. Conser. Mar. Lab., Prof. Pap. Ser. No. 3. 139 p.

Grimes, C. B. 1971. Thermal addition studies of the Crystal River Steam Electric Station. Fla. Dept. Nat. Res., Mar. Res. Lab., Prof. Pap. Ser. No. 11. 53 p.

Grimes, C. B. 1975. Entrapment of fishes on intake water screens at a steam electric generating station. Chesapeake Sci. 16(3):172-177.

Landry, A. M. and K. Strawn. 1974. Number of individuals and injury rates of fishes caught on revolving screens at the P. H. Robinson Generating Station. Pages 263-271. In L. D. Jensen, ed. Entrainment and intake screening. Proc. 2nd Entrainment and Screening Workshop. Rep. No. 15, Edison Electric Inst. 347 p.

Lewis, A. 1975 . The horseshoe crab, a reminder of Delaware's past. Mar. Adv. Ser., No. 6. Univ. Delaware. 3 p.

Lindall, W. N., W. A. Fable, Jr., and L. A. Collins. 1975. Additional studies of the fishes, macroinvertebrates, and hydrological conditions of the upland canals in Tampa Bay, Florida. Fish. Bull. 73(1).

Mathur, D., P. G. Heisey, and N. C. Magnusson. 1977. Impingement of fishes at Peach Bottom Atomic Power Station, Pennsylvania. Trans. Amer. Fish. Soc. 106(3):258-267.

Phillips, T. D. 1977. Ichthyoplankton. Chapter 5. In Tampa Electric Company. Twenty-eighth quarterly report on the Big Bend thermal and ecological surveys. Contains twenty-fifth quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 651 p.

Reid, G. K. 1954. An ecological study of the Gulf of Mexico fishes in the vicinity of Cedar Key, Florida. Bull. Mar. Sci. Gulf and Caribbean. 4(1):1-94.

Springer, V. G. and K. D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. Fla. Bd. Conserv. Mar. Lab., Prof. Pap. Ser. No. 1. 104 p.

United States Department of Commerce. 1975. Current fisheries statistics. Gulf coast shrimp data. Annual summary, 1975. NOAA. 26 p.

Voigtlander, C., D. A. Tomlyanovich, and W. C. Barr. 1976. Assessment of impingement impacts on TVA reservoirs. A paper presented at the Third National Workshop on Entrainment and Impingement. New York, New York.

Appendix 7. A. Seasonal abundance of invertebrates and vertebrates impinged during the day and night.

	INVERTEBRATES			VERTEBRATES			
	Day	Night	Total	Day	Night	Total	Total
Jan.- Mar.	945	1509	2454	120	195	315	2769
Apr.-June	418	646	1064	451	888	1339	2403
July-Sept.	1075	1454	2529	603	1901	2504	5033
Oct.-Dec.	721	572	1293	1017	835	1852	3145
Jan.-Mar.	790	1252	2042	1871	2065	3936	5978
TOTALS	3949	5433	9382	4062	5844	9946	19328

Appendix 7.B . Comparison of impingement with the intake structure lights on and with the lights off. (1=0001-0600 hrs; 4=1800-2400 hrs).

Lights Off

Date(1976)	Time	Total Vertebrates	Total Invertebrates	Total Individuals	Total Species
1/24	1	46	162	208	21
	4	93	383	476	23
2/10	1	4	164	168	14
	4	1	61	62	12
2/17	1	3	130	133	13
	4	12	102	114	17
3/5	1	4	88	92	9
	4	8	36	44	9
3/19	1	5	60	65	8
	4	7	75	82	14
TOTALS		183	1261	1444	

Lights off

Date(1976)	Time	Total Vertebrates	Total Invertebrates	Total Individuals	Total Species
1/21	1	12	94	106	16
	4	23	289	312	17
2/5	1	81	319	400	29
	4	15	93	108	13
2/16	1	20	233	253	19
	4	7	21	28	12
3/3	1	6	74	80	8
	4	3	102	105	9
3/17	1	16	173	189	12
	4	7	76	83	11
TOTALS		190	1474	1664	

Appendix 7. C. A list of fishes and macroinvertebrates that were impinged on the travelling screens between January, 1976 and March, 1977. (For more information, refer to previous quarterly reports).

Macroinvertebrate Species	Jan.-Mar.	April-June	July-Sept.	Oct.-Dec.	Jan.-March
Aurelia aurita	X	X	X	X	
Chrysura quinquecirrha			X	X	X
Aplysia willcoxi		X			
Lolliguncula brevis	X	X	X	X	X
Squilla empusa	X	X	X	X	X
Limulus polyphemus	X	X	X	X	X
Penaeus duorarum	X			X	X
Trachypenaeus constrictus	X	X		X	X
Alphèus heterochalis	X	X		X	X
Upogebia sp.		X			
Petrolisthes armatus	X			X	X
Petrolisthes sp.			X	X	
Pagurus longicarpus				X	X
Portunus gibbesii	X		X	X	X
Portunus sp.			X	X	
Callinectes ornatus	X	X			
Callinectes sapidus	X	X	X	X	X
Callinectes sp.			X	X	
Menippe mercenaria	X	X	X	X	X
Hexapanopeus angustifrons		X	X		
Neopanope texana texana	X	X	X	X	X
Eurypanopeus depressus	X	X	X	X	X
Panopeus herbstii	X	X	X	X	X
Sesarma cinerium	X	X	X	X	X
Sesarma reticulatum	X	X	X	X	X
Libinia dubia	X		X		X

Appendix 7.C. (continued) A list of fishes and macroinvertebrates that were impinged on the travelling screens between January, 1976 and March, 1977. (For more information, refer to previous quarterly reports).

Macroinvertebrate Species	Jan.-Mar.	April-June	July-Sept.	Oct.-Dec.	Jan.-March
Mogula sp.	X	X	X	X	X
Vertebrate Species					
Sphyrna tiburo				X	
Dasyatis americana			X		
Dasyatis sayi		X			
Gymnura micrura	X				X
Rhinoptera bonasus					X
Elops saurus					X
Ophichthus gomesi					X
Harengula jaguana		X		X	X
Opisthonema oglinum	X		X	X	X
Anchoa hepsetus				X	X
Anchoa mitchilli	X	X	X	X	X
Synodus foetens	X				
Arius felis	X		X	X	X
Bagre marinus				X	
Opsanus beta	X	X	X	X	X
Porichthys porosissmus	X				
Gobiesox strumosus	X	X	X		
Urophycis floridanus					X
Hyporhamphus unifasciatus	X	X			
Strongylura timucu					X
Cyprinodon variegatus					X
Lucania parva		X			
Membras martinica	X			X	X
Menidia beryllina	X	X			X

Appendix 7.C. (Continued) A list of fishes and macroinvertebrates that were impinged on the travelling screens between January, 1976 and March, 1977. (For more information, refer to previous quarterly reports).

Vertebrate Species	Jan.-Mar.	April-June	July-Sept.	Oct.-Dec.	Jan.-March
Hippocampus erectus	X	X		X	X
Syngnathus louisianae					X
Syngnathus scovelli				X	
Caranx hippos					X
Chloroscombrus chrysurus		X	X	X	X
Hemicaranx amblyrhynchus			X	X	
Oligoplites saurus			X	X	
Selene vomer			X	X	
Diapterus plumieri	X			X	
Eucinostomus argenteus	X	X	X	X	X
Eucinostomus gula	X	X	X	X	X
Orthopristis chrysoptera		X	X	X	X
Archosargus probatocephalus			X		
Lagodon rhomboides	X	X	X	X	X
Bairdiella chrysura	X	X	X	X	X
Cynoscion arenarius	X	X	X	X	X
Cynoscion nebulosus		X	X	X	X
Leiostomus xanthurus		X			
Menticirrhus americanus		X			
Menticirrhus saxatilis		X		X	X
Micropogon undulatus		X			
Sciaenops ocellata	X	X		X	X
Chaetodipterus faber	X	X	X	X	X
Mugil cephalus		X			

Appendix 7.C. (Continued) A list of fishes and macroinvertebrates that were impinged on the travelling screens between January, 1976 and March, 1977. (For more information, ref r to previous quarterly reports).

Vertebrate Species	Jan.-Mar.	April-June	July-Sept.	Oct.-Dec.	Jan.-March
Astroscopus y-graecum		X		X	
Hypsoblennius hentzi	X			X	X
Bathygobius soporator			X		
Prionotus scitulus	X	X	X	X	X
Prionotus tribulus	X	X		X	X
Achirus lineatus	X	X	X	X	X
Trinectes maculatus			X	X	X
Symphurus plagiusa	X	X	X	X	X
Monocanthus hispidus	X	X		X	X
Acanthostracion quadricornis					X
Sphoeroides nephalus	X	X		X	X
Chilomycterus schoepfi	X	X	X	X	X

Appendix 7.D. Seasonal abundance of the total number of individuals impinged during the four sampling periods. (1 = 0001-0600 hrs; 2 = 0601-1200 hrs; 3=1201-1800 hrs; 4 = 1801-2400 hrs).

	Jan.-Mar.	April-June	July-Sept.	Oct.-Dec.	Jan.-Mar.	Total
1	1029	692	1810	795	2118	6444
2	325	609	837	849	2001	4621
3	740	260	841	889	660	3390
4	675	842	1545	612	1199	4873
TOTAL	2769	2403	5033	3145	5978	19328

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CHAPTER EIGHT

AN ASSESSMENT OF THE IMPACT OF THERMAL DISCHARGE ON FISH AND MACROINVERTEBRATE COMMUNITIES AT BIG BEND, TAMPA (FLORIDA)

BY

GARY S. COMP

AUGUST, 1977

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LIST OF PARTICIPANTS

PRINCIPAL INVESTIGATOR:	Gary S. Comp B.A. Staff Biologist
RESEARCH ASSISTANTS:	Calvert N. Courtney II Marine Science Technician
	Brightman S. Logan Marine Science Technician
	Charles Morris B.S. Staff Biologist

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INTRODUCTION

The increasing demand for electrical energy has continually warranted expansion of the power industry. The potential of debilitating effects, resulting from power plant operation, has proportionately increased as these plants discharge waste heat into marine and aquatic environments.

The direct effects of thermal discharge can fluctuate between beneficial and detrimental, depending partially on the site location, the season, and the extent of water temperature increase attributable to power plant operation. Thermal effluent may affect organismic physiological or chemical processes. The effects may be beneficial, e.g. enhancing the growth rates of certain species, or detrimental, e.g. causing a synergistic effect with a pollutant already present in the water.

Generally, most effects are concentrated in an area around the discharge site. Roessler and Tabb (1974), in a study at the Turkey Point nuclear power plant (Biscayne Bay, Florida), found that a localized area of three hundred acres was detrimentally affected by the thermal discharge.

The warm water which permeates the discharge area can influence abundance and diversity values, depending on the season. Studies at the Crystal River Power Plant (Grimes, 1971) showed that diversity increased with distance away from the outfall in summer and toward the outfall in winter. Gallaway and Strawn (1974) found that a seasonal change in abundance and distribution patterns of dominant fish species was occurring in the discharge area of a generating station on Galveston Bay. However, they concluded that, overall, the detrimental effects of the heated effluent were negligible on the fish fauna in the discharge area.

Changes in fish populations or in community structure may occur as a direct result of physiological stress, or as a response to a change in a lower trophic level, e.g. a plankton community. If a temperature increase causes the reduction or elimination of a source of food, changes in community structure may become evident as certain species are forced to move elsewhere in search of a suitable food supply.

However, not all fish movement can be interpreted as a response to a stress induced situation. Fish populations are generally characterized by constant movement in response to feeding, breeding and seasonal patterns. Drastic deviation from such established (natural) patterns could, however, indicate a stressed environment.

Fish and macroinvertebrate populations in the vicinity of Tampa Electric Company's Big Bend steam electric station, have been monitored on a quarterly basis since 1970. This baseline information (1970 - 1975) has been summarized in a previous report (TECO, 1975).

In January 1976, a "316 (a) and (b) demonstration" was initiated at the study site. These studies continued through March, 1977. The results and conclusions derived from the seine and trawl collections of this study are presented in this final report.

Specific Objectives

The purpose of this section of the 316 demonstration is to assess the effects of thermal discharge on the fish and macroinvertebrate populations in the vicinity of the Big Bend Steam Electric Station. To ensure a comprehensive impact assessment, the following factors were considered:

1) the species composition and community structure of the fish and macroinvertebrate populations in the area;
2) the relative abundance of these species;
3) the migratory and seasonal habits of the indigenous and transient species;
4) nursery areas;
5) the distribution of commercially important species;

6) changes in the species composition or relative abundance that could be directly or indirectly attributed to the discharging of the thermal effluent; and
7) the long term implications of changes in community structure, if such changes are the result of thermal alteration of habitats.

Sampling Scope and Limitations

Inherent limitations are prevalent in any study that involves actively sampling fish populations. If similar methods of sample collection and data analysis are utilized throughout the period of study, these limitations should not reduce the validity of the study for detecting trends.

The number of replicates that are required at each station to adequately sample a given population, is site and season specific. In the present study, two replicate seine hauls or trawl tows were collected at each station. The biological staff of Conservation Consultants, Inc., along with representatives from the Environmental Protection Agency, the Florida Department of Environmental Regulation and the U. S. Fish and Wildlife Service felt that this number (of replicates) would be sufficient to achieve the specific objectives of this study.

Previous studies have supported this decision. The use of three or less replicate hauls or tows per station is a widely accepted sampling method which has been implemented in various ecological studies (Gallaway and Strawn, 1974; Haedrich and Haedrich, 1974; McErlean, O'Connor, Mihursky and Gibson, 1973; Bechtel and Copeland, 1970; Dahlberg and Odum, 1970). Depending on the area being sampled, the number of trawl replicates may vary between 7 and 10 (Livingston, 1975; Roessler and Tabb, 1974; and Roessler, 1965).

The data collected in this study was not subjected to rigorous statistical analysis (and testing) because of the inherent problems associated with fitting catch data to statistical hypotheses. However, we did utilize certain specific statistical methods to provide a baseline for comparing our results with those of previous studies, and to allow a mathematical comparison of catch data between stations, seasons, and thermally affected and non-affected areas. Conclusions of this study were not, however, based solely on the interpretation of statistical analyses.

Sampling limitations should not significantly affect the results of a study if standardized sampling methods are incorporated. McErlean, et al. (1973) stated that serial comparisons of successive samplings using the same method are justifiable. Katz and Gaufin (1953) found such obvious differences in the fish populations they sampled, that the sampling errors were relatively unimportant. Regardless of the limitations of sampling with a seine, Subrahmanyam and Drake (1975) were able to show seasonal patterns and changes in communities related to tides in a Florida salt marsh.

From previous literature, it appears that comprehensive analysis and interpretation of data, collected by a limited number of replicates over a long period of time, is a valid approach to attain the goals of this study. We feel, therefore, that sampling errors were within reason and that there is little, if any, doubt concerning the validity of the conclusions arrived at during the recent study.

Specific Limitations of the Sampling Gears

The detection of changes in abundance or species composition does not necessarily imply that these changes can be attributed to thermally altered water.

The spatial and temporal distribution of fishes and macroinvertebrates often biases sample collections. Highly mobile fishes can avoid a net simply by swimming away from the net's path. Otter trawls are generally selective for bottom dwelling species and some schooling species which frequent areas close to the bottom.

The type of substrate over which sampling occurs can influence net efficiency. A muddy or irregular bottom can inadvertantly cause a trawl to bog down, thereby decreasing its effectiveness. A rocky bottom may cause the lead line of a seine to rise off the bottom and allow individuals to escape underneath.

The dimensions of the sampling net may influence its efficiency. Kjelson (1977) implied that, while absolute catch efficiency was 52% for a 6.1 m trawl for juvenile pinfish (Lagodon rhomboides), absolute catch efficiency for this same species would drop to 8% if a 3.0 m trawl was used.

Since a 3.0 m trawl was used in this study, the catch efficiency may have been low.

METHODS

Seine Stations

Seine sampling was conducted monthly at six stations. Sampling sites were chosen on the basis of their proximity to or distance from the thermal plume, substratum composition and type of habitat.

The station locations are depicted in Figure 8.1, and described in Table 8.1 (also see Comp and Morris, 1976; and Comp, 1976).

Sampling

The seine used in this study was 150′ x 6′, and was constructed of 3/4 inch stretch mesh multifilament nylon. A bag (4′ x 4′ x 12′) constructed of 1/2 inch stretch mesh multifilament nylon was added to the center of the seine to facilitate the collection of specimens. A 6′ x 10′ panel

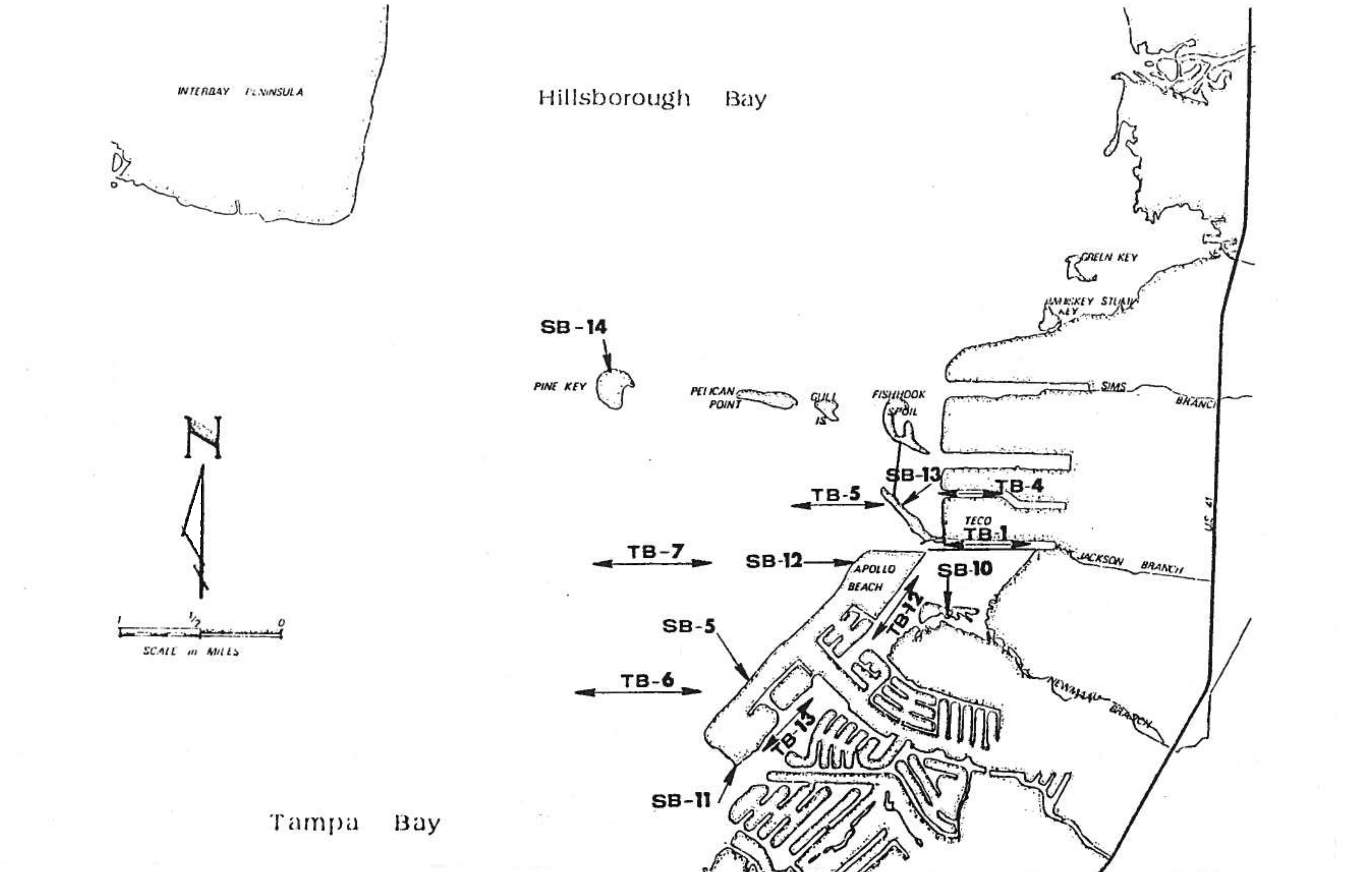


Figure 8.1. Seine stations (SB) and trawl stations (TB) at Big Bend.

Table 8.1. Outline of Big Bend Seine Stations.

Station	Substrate Composition	Thermal Plume +	Location	Comments
SB-12	Sand	Within	Open bay; N.W. end of Apollo Beach	Shallow area; numerous sandbars.
SB-5	Sand	Outside	Open bay; S.W. end of Apollo Beach	Shallow area; some rocks extend beyond the littoral zone.
SB-14	Sand	Farfield region	Open bay; north shore of Pine Key	Sloping beach; bordering a ship channel.
SB-10	Mud	*	Inshore; north embayment	Very shallow area; much of it exposed during a low tide. Seasonal algal growth.
SB-11	Sand	Outside	Inshore; south embayment; S.E. end of Apollo Beach	Shallow point; bordering a ship channel.
SB-13	Sand	Outside	Inshore; west of intake canal	Shallow area; source water for the plant.

+Refers to the thermal plume as outlined in the hydrographic section of this report.

*Discharge water penetrates this area during an incoming tide. However, due to the shallowness of this area, solar heating probably exerts a greater influence on water temperature than the thermal discharge.

of 1/2 inch stretch mesh multifilament nylon was added to the body of the seine on both sides of the bag.

The seine was deployed by boat at all but one (SB-10) of the sampling stations. One end of the net was anchored to shore. The remaining net was payed out as the boat was backed perpendicular to the shore. A half circle configuration was then formed as the boat dragged the net toward shore. The seine was then hauled onto the beach. Duplicate hauls (2) were taken at each station.

It was not feasible to use the boat at station SB-10, due to the shallowness of this area. Instead the seine was set and hauled by hand.

To assess sampling efficiency, five replicate seine hauls (instead of two) were taken at two different stations on consecutive days. This procedure was implemented once during this study.

Trawl Stations

Trawl samples were collected along seven transects each quarter. The transect sites were chosen on the basis of their location in relation to the thermal plume, depth, substratum composition, and habitat. Transect locations are depicted in Figure 8.1 and described in Table 8.2.

Table 8.2. Outline of Big Bend trawl transects.

Station	Substrate Composition	Bottom Pattern	Thermal Plume *	Average Depth (m)	Depth Range (m)	General Location
TB-1	Sand	Smooth	Within	4.9	4.6 - 5.2	Discharge Canal
TB-5	Sand	Smooth	Within	2.4	1.8 - 3.0	Open Bay
TB-7	Mud	Smooth	Within	3.3	3.0 - 3.6	Open Bay
TB-6	Mud	Smooth	Outside	3.6	3.0 - 4.3	Open Bay
TB-13	Mud	Irregular	Outside	4.0	3.0 - 5.2	Southern Embayment
TB-12	Mud	Irregular	+	3.6	2.4 - 4.6	Northern Embayment
TB-4	Mud	Smooth	Outside	5.8	5.5 - 6.1	Intake Canal

+Thermal effluent penetrates this area during an incoming tide.

*Refers to the thermal plume boundaries as outlined in the hydrographic section of this report.

Sampling

A 10' otter trawl constructed of 1 1/2 inch stretch mesh multifilament nylon was used during this study. A 4' bag constructed of 1/4 inch ACE nylon was added to the cod end to facilitate the capture of small specimens.

The trawl was towed behind a 24' Pro-line boat equipped with twin 85 h.p. engines. To minimize variability in tow duration, all tows were scaled to the shortest transect (intake canal). Approximately five minutes were required to trawl the intake canal at a speed of 2-3 knots. Therefore, the remaining transects were sampled for a comparable period of time and speed. Duplicate tows (2) were made along each transect. In an attempt to further reduce variation, replicate tows were made in the same direction as the inital tow at each station.

To assess sampling efficiency, five replicate tows (instead of two) were taken along two different transects on consecutive days. This procedure was implemented once during this study.

Seine and Trawl

Physical and Chemical Parameters

Physical and chemical parameters were recorded at each station using the instruments outlined as follows:

Parameter	Measuring Instrument
Air Temperature	Mercury Thermometer (-20 °C to 50 °C)
DO and Water Temperature	YSI Model 54 Pressure Compensated Oxygen Meter
Salinity	YSI Model 33 S-C-T Meter
Turbidity	Hach Model 2100 A Turbidimeter
Depth	Ray Jefferson Model 5300 Recorder/Flasher

The following parameters were measured at the seine stations after the second replicate haul was made: wind speed and direction; air temperature; and surface readings of water temperature, dissolved oxygen, salinity, and turbidity. When possible, these readings (except turbidity) were also measured two weeks following a seine sample collection so that changes in these parameters could be monitored more efficiently.

The following parameters were measured at the beginning and end of the second replicate tow along trawl transects: wind speed and direction; air temperature; depth; surface and bottom readings of air temperature, dissolved oxygen, and salinity; and bottom measurements of turbidity.

Laboratory Methods

All specimens were preserved in the field in 10% buffered formalin and seawater. The individuals were sorted, identified, weighed (wet weight to the nearest 0.1 g), and measured (standard length to the nearest 1 mm) at the laboratory.

Up to 75 individuals per species per replicate were measured and sorted into 10 mm size classes. Total weight was obtained by combining the weights of all the size classes. If the total number of individuals of a single species exceeded 75 in one replicate, a random sample of 75 individuals were measured, sorted, and weighed. The balance was counted and weighed as a group.

Certain species (*Fundulus similis*, *Menidia beryllina*, *Membras martinica*, *Lagodon rhomboides* and *Mugil cephalus*) were weighed and measured individually (up to 75 individuals per replicate) so that a condition factor could be calculated.

Random samples of selected species were dissected each month and were cursorily examined for gonad development and stomach contents.

Data Reduction and Analyses

A variety of bioindices and statistical tests were utilized to aid in the interpretation of data. A Data General Nova 3 computer was used to generate the bioindices listed below. The statistical procedures and tests were calculated with a Texas Instruments SR-52A programmable calculator. The reader is referred to the Benthic Section of this report for a more detailed description of the computer facilities.

The reader is referred to Mahadevan (1976) for a detailed description of some of the following indices.

Bioindices

1) Shannon-Weaver Index of Diversity (Shannon and Weaver, 1963).

$$H' = {}^{C}/N\ (N \log_{10} N - ni \log_{10} ni)$$

2) Margalef's Species Richness Index (Margalef, 1958)

$$D = {}^{S-1}/\log N$$

3) Pielou's Equitability Index (Pielou, 1966)

$$J' = H'/\log S$$

4) Morisita's Index of Similarity (Morisita, 1959)

$$C\lambda = 2 \sum_{i=1}^{S} \frac{n_{1i} \quad n_{2i}}{(\lambda 1 + \lambda 2)}\ (N_1\ N_2)$$

5) Condition Factor (Modified from Lagler, 1956)

$$K = \frac{W \times 10^5}{L^3}$$

W = weight in grams

L = standard length in mm

K = condition factor

Statistical Procedures and Tests

1) Multiple Regression (Snedecor and Cochran, 1967).

2) Linear Regression (Snedecor and Cochran, 1967).

3) Student's T-test (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Seine

Physical and Chemical Parameters

Of the parameters that were monitored during this study, water temperature and salinity probably would exert the greatest influence on estuarine community structure.

The annual averages and ranges of these two parameters are outlined below. The monthly values of these parameters have been presented in previous reports (Comp and Morris, 1976; Comp, 1976; Comp, 1977a; Comp, 1977b) and in TECO, (1977).

Station	Temperature °C Average	Range	Salinity o/oo Average	Range
SB-12	25.4	15-34	23.8	20-29
SB-5	24.1	14-32	23.7	20-29
SB-14	22.8	12-31	23.1	18-27
SB-10	25.8	18-34.5	23.6	19-27
SB-11	23.8	16-32.5	23.7	20-29
SB-13	24.2	12-34	23.4	19.5-27

The highest yearly average water temperature (25.8°C) occurred at station SB-10 (northern embayment). Due to the shallowness of this station, solar heating probably exerted a greater influence than the thermal discharge on the water temperature in this area.

The greatest influence that the thermal discharge had at any one seine station occurred at station SB-12 (northwest end of Apollo Beach). This area is inundated by the effluent as it enters Hillsborough Bay. The yearly average water temperature at this station was 25.4°C. Station SB-5 (approximately 1500 m. south of SB-12) is out of the range of the thermal plume. Water temperature at this station averaged 24.1 °C for the fifteen month period. When the bi-monthly readings were taken, the water temperature at SB-5 was usually 2°C cooler than the water temperature at SB-12. Since these two stations have similar locations, depths and substrata, the thermal effluent must be directly responsible for the temperature differences that were noted between these two stations. The water temperatures at these two stations have been plotted in Figure 8.2.

The water temperature at the seine stations correspond to seasonal fluctuations in air temperature. Solar heating also contributed to the high temperatures that were recorded at some stations outside of the thermal plume boundaries.

Dissolved oxygen and salinity values probably did not fluctuate enough to be limiting factors in community structure, abundance, or distribution. Salinity ranged from a high of 29 °/oo at stations SB-5, SB-12, and SB-11 in May, 1976 to

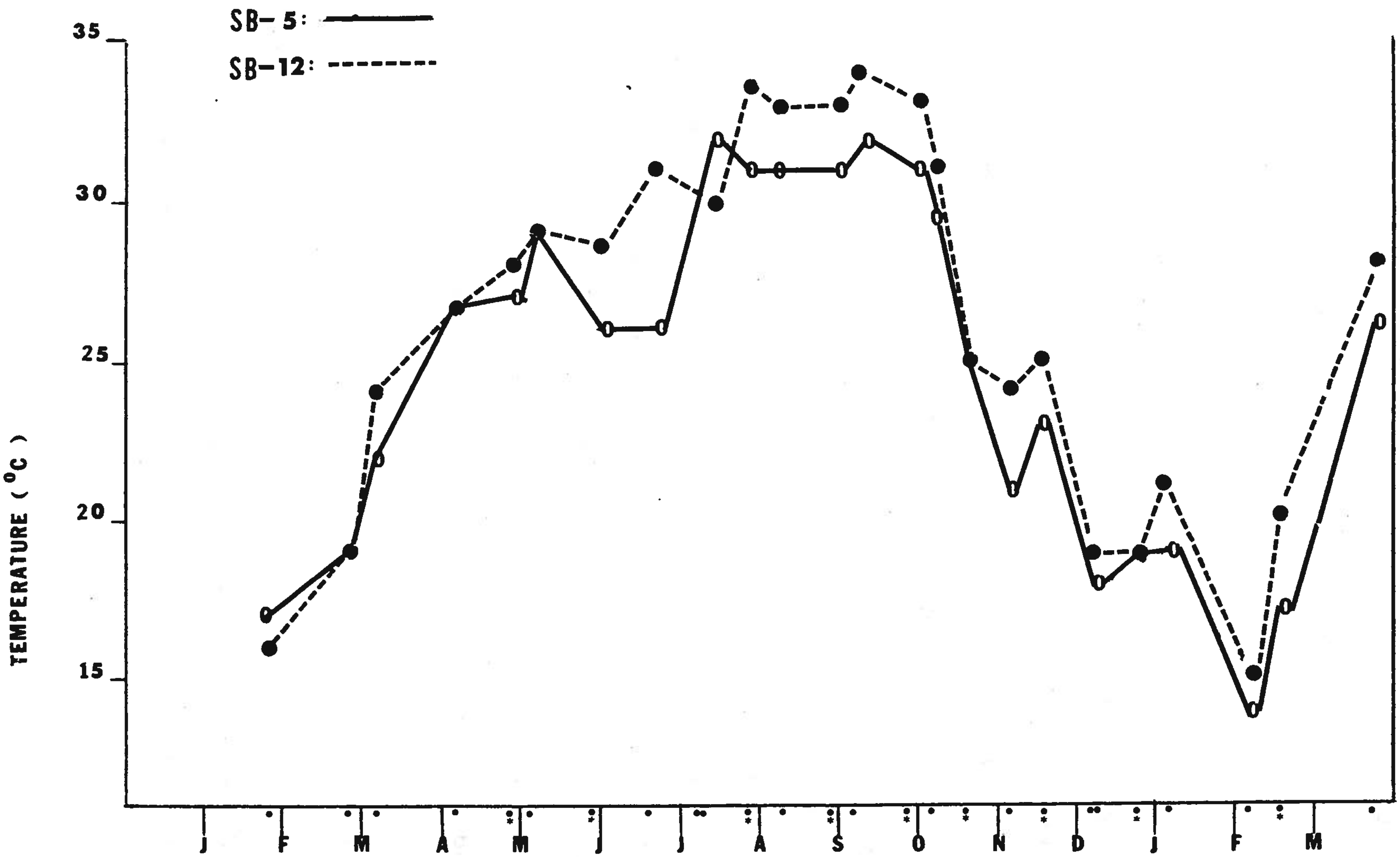


Figure 8.2. Water temperature values at seine stations SB-5 and SB-12.

* Temperatures on these dates were recorded within a few minutes of each other. At least one hour elapsed between sampling times on the other dates.

a low of 18 $^{o}/oo$ at stations SB-12 and SB-14 in February, 1977. DO fluctuated between a high of 11.7 ppm at station SB-5 in February, 1976 to a low of 5.0 ppm at station SB-10 in August, 1976.

Systematic Account

The following is a systematic account of some of the fishes and macroinvertebrates that were collected by seine between January, 1976 and March, 1977. The species listed in this account were chosen on the basis of their commercial importance in the Tampa Bay area and/or their relative abundance in the seine catches.

When possible, these data will be compared with the baseline data that was collected in this area prior to the inception of this program. A table presented by Phillips (1976a) will be the primary source of information for this comparison. This table lists, by season, the total number of fishes that were collected with seines, trawls, travelling screens, and crab traps between fall, 1970 and fall, 1975.

Information, compiled from studies that were conducted in relatively unstressed areas, is also included in this account. This enables a comparison of the trends noted in the Big Bend area to those of other studies. Deviations from usual life histories could be indicative of a stressed environment.

The ranges listed in this account refer to the ranges that were observed (measured) between January, 1976 and March, 1977.

The generic and common names of the fishes listed in this account follow those of the American Fisheries Society (Bailey, et al., 1970).

Harengula jaguana
Scaled sardine
Number collected: 1721
Size range: 62-138 mm
Temperature range: 12-34^{o}C
Salinity range: 18-25 ^{o}/oo

The scaled sardine was formerly referred to as *H. pensacolae*. Whitehead (1973) has presented evidence which indicates that *H. jaguana* is the correct generic name for this species.

H. jaguana is an inhabitant of the open bay in the Big Bend area. All but 3 of the 1721 specimens collected between January, 1976 and March, 1977 were captured at seine stations on the open bay. Most of the individuals (98%) were captured during the summer and fall months. This corresponds to the time when Springer and Woodburn (1960) found this species in abundance.

This species apparently inhabits the Big Bend area in all but the winter months. Although few adults were captured before late summer, Phillips (1976b, 1977) reported the presence of eggs and larvae of this species in the Big Bend area between late April and July. The adults apparently spawn in offshore waters during this time (April - July) and are not accessible by our sampling methods. Springer and Woodburn (1960) indicated that spawning of this species occurs in April and May.

There are conflicting reports concerning the influence of temperature and salinity on this species. Springer and Woodburn (1960) in their study of Tampa Bay, and Gunter (1945) in his study of the Texas Coast, caught few _H. jaguana_ when salinity concentrations dropped below 25 $^{o}/oo$. In the Big Bend area, _H. Jaguana_ was most abundant at the Pine Key station (SB-14), during September and October. Salinity values at the time of sample collection were 22 and 23 $^{o}/oo$ for September and October respectively.

Gunter (1945) also noted the disappearance of _H. jaguana_ when water temperature fell below 24^{o}C. However, Reid (1954) captured individuals of this species in March, when surface water temperature was 20.8^{o}C and Mountain (1972) captured specimens at a temperature of 17.1^{o}C. We captured one specimen in November when the water temperature was 20^{o}C and 2 specimens the following February when the water temperature was 14°C. The coldest water temperature at which Springer and Woodburn (1960) captured live specimens was 16.8°C. They found 2 cold-killed specimens after a severe cold wave. The water temperature had dropped to 13°C. Those that we captured at 14°C showed no ill-effects as a result of low water temperature, even though this temperature was apparently close to their lethal minimum temperature.

Scaled sardines were collected at temperatures as high as 35.1°C by Springer and Woodburn (1960) and 37.9°C by Springer and McErlean (1962).

Anchoa mitchilli Valenciennes
Bay anchovy
Number collected: 9171
Size range: 18-65 mm
Temperature range: 16-32°C
Salinity range: 20-24 °/oo

A. mitchilli were abundant in seine catches in October through December, 1976 and again in February and March of 1977.

Most of the specimens were collected at shallow inshore stations, and were probably utilizing these areas as nursery grounds.

An extended spawning season was indicated since two distinct groups of young individuals inhabited the shallows at two different times. Those individuals collected in October through December had a mean standard length of less than 31 mm. Those collected in February had a mean standard length of less than 26 mm. Phillips (pers. comm.) indicated that an extended spawning season (between March and October) occurs in the Big Bend area. Gunter (1945) also noted that the spawning season for this species in Texas, may extend from spring through fall.

Bay anchovies have been collected at temperatures as low as 7.9°C (Dahlberg, 1972) and as high as 32.5°C (Springer and Woodburn, 1960). Salinity extremes range from 0 °/oo (Tabb and Manning, 1961) to 35 °/oo (Springer and Woodburn, 1960).

<u>Cyprinodon</u> <u>variegatus</u> Lacépède
Sheepshead minnow
Number collected: 2961
Size range: 14-58 mm
Temperature range: 14-34.5°C
Salinity range: 19-27 °/oo

<u>C</u>. <u>variegatus</u> were captured consistently at station SB-10, an embayment station. Of the 2,961 individuals that were collected, only 28 were found at stations other than SB-10. The relative abundance of this species at this station reflects its habitat preference (Martin, 1972; Springer and Woodburn, 1960; Kilby, 1955).

This species was collected during every month, but it was most abundant from May through August, 1976. The fish is eurythermal (Springer and Woodburn, 1960) and has been collected in areas where the water temperature ranged from 8.8 to 34.9°C (Gunter, 1945).

The greatest decrease in the relative abundance of this species between two sampling periods, occurred between August and September, 1976. A total of 449 individuals were captured at SB-10 in August, as opposed to a total catch of only 11 at SB-10 in September. Water temperature at this station rose from 32 to 34.5°C between the August and September collections. Abundance levels rose to 94 individuals captured at SB-10 in November. A corresponding decrease in water temperature (to 28°C) was also noted.

While this species is eurythermal, it is possible that temperatures above 35°C are approaching the critical thermal maximum for this species.

Young specimens ($\bar{X}$ SL $\leq$ 20mm) were captured in April, May, November and December, 1976, and January, 1977. These results contradict the findings of Springer and Woodburn (1960) who felt that spawning apparently occurred only during the summer months. Kilby (1955) thought that spawning could occur year-round in the warmer waters of the Gulf.

<u>Fundulus</u> <u>similis</u> (Baird and Girard)
Longnose killifish
Number collected: 7704
Size range: 9-117mm
Temperature range: 12-34.5°C
Salinity range: 18-29 ‰

This was one of the most ubiquitous and abundant species captured within the course of this study, and during several preceeding years (Phillips, 1976a). Specimens were captured at 3 to 6 seine stations each month.

Growth progression was outlined in Table 8.3. Young specimens ($\bar{X}$ SL$\leq$ 23 mm) were captured almost every month, thus indicating year-round spawning activity. Kilby (1955) also found young specimens in his collections throughout the seasons.

Other studies show temperature and salinity ranges for longnose killifish of 13.0 - 33.5°C and 3.2 - 76.1 °/oo (Mountain, 1972; Springer and Woodburn, 1960; Simpson and Gunter, 1956).

The distribution of this species did not appear to be influenced by temperature or salinity variations.

Menidia beryllina (Cope)
Tidewater silverside
Number collected: 20,256
Size range: 14-96mm
Temperature range: 12-34.5
Salinity range: 18-29

M. beryllina was abundant in the area throughout this sampling period. It has been common in the catches collected at Big Bend during the previous several years (Phillips, 1976a). Individuals were collected at atleast 4 seine stations (usually 5 or 6) each month during the present study.

Growth rates are presented in Table 8.4 but patterns are difficult to discern. The presence of young individuals ($\bar{X}$ SL $\leq$ 23mm) was apparent in January (1977), February (1976 and 1977).

Table 8.3. Growth progression of <u>Fundulus similis</u> captured by seine between January, 1976 and March, 1977.

Mid Class (mm)	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
8			1												
11											5				
14											11				
17					1		1			1	26	16			
20											13	7	1	1	
23				1	1			1			5	1	3		1
26		1		1	3						17	2		2	1
29					4	1			1		6	2	1	2	2
32					8		1				3	1	4	8	1
35					17	1	3	5			1	3	8	15	1
38			1		52	2	10	11	3	1	3	2	16	15	3
41		2	2	10	20	19	23	22	13	1	4	7	13	9	3
44		7	6	13	22	29	9	30	10	6	8	4	12	16	5
47	1	10	5	16	14	27	11	22	13	10	4	12	25	16	1
50		5	4	20	6	17	17	36	19	6	6	3	16	17	6
53	1	5	6	15	6	18	24	36	17	7	3	8	13	11	2
56		4	4	17	3	21	24	34	32	9	1	8	11	9	16
59	2	4	4	16	7	5	27	33	29	13	9	16	14	14	8
62	2	6	1	14	4	9	12	21	16	19	6	14	9	8	13
65	3	4	9	12	5	4	14	22	28	25	7	24	11	7	25
68	4	10	7	6	2	6	5	15	14	18	12	26	11	14	18
71	4	15	7	7	4	4	2	8	13	14	14	25	25	28	17
74	3	25	8	5	11	2	4	9	9	12	14	29	24	26	21
77	3	30	8	2	4	1	4	8	5	7	8	20	43	20	15
80	4	34	12	2	9	1	4	4	4	10	13	23	46	26	17
83	5	42	9	3	8	1	6	1	4	9	8	11	29	13	10
86	4	33	13	5	10	1	1	1	4	5	9	6	30	12	16
89	7	36	6	4	15	3		1	3	2	4	1	29	9	8
92	6	27	9		8				2	5	1	2	18	5	14
95	7	22	10	2	14	1				5	1	3	9	9	5
98	2	22	12	1	11	2		1	1	2		2		3	8
101	1	20	7	3	11	1	1	2	2	4			5	3	3
104		13	7		7	1				1			2	3	2
107		7	1		4					2	1				
110		8	1	1							1				
113		2													
116		3													
119									1						
TOTAL	59	397	160	176	291	179	204	323	243	194	224	278	748	321	242

Table 8.4. Growth progression of *Menidia beryllina* captured by seine between January, 1976 and March, 1977.

Mid Class (mm)	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
11		1													
14		1	1	4	1					1					
17		6		3						1	1	4	5		
20		9		18	5					1			5	1	
23		7		11	6				1	2		3	7	2	
26		5		13	7	1				2	1	2	7	1	2
29		16	2	2	14					1	5	13	16	2	
32		3	3	4	7			1			4	22	23		
35		2	6	8	2			1	1		3	20	6	1	2
38			11	4	2	1		7		2	1	5	11	1	1
41	1	1	16	12	4	2	2	9	3	8	5	12	19	1	
44	1	3	10	15	11	25	10	38	5	29	5	10	9	2	1
47	1	10	16	6	34	74	50	103	24	28	33	10	21	4	2
50	2	15	14	11	53	105	94	143	45	70	65	26	30	9	5
53	1	16	20	5	55	92	103	114	76	72	80	52	25	13	10
56	3	16	14	3	39	52	106	103	93	84	70	83	62	23	10
59	1	8	6	6	13	15	56	69	132	72	87	83	53	46	23
62	6	4	3	3	12	9	24	34	108	63	71	77	67	43	32
65	11	13	4	1	4	6	11	13	60	59	87	64	62	55	30
68	9	33	22	1	11	1	3		28	23	75	63	73	79	47
71	48	35	61	2	4				20	6	42	67	98	65	68
74	26	56	67	8	4		1		9	9	26	42	104	77	56
78	30	60	53	9	1	2	1		8	12	9	24	43	45	55
80	18	32	45	4	6	1				3	9	11	53	42	59
83	9	40	40	6	1						7	12	28	32	24
86	7	21	30	4	2						6		16	19	20
89	1	20	16	1							2	1	17	12	16
92	2	4	7										2	4	7
95		2	7											1	3
98															
TOTAL	177	438	474	164	298	386	461	635	613	548	694	706	862	580	473

March, April, May, September, October, November and December, 1976. Ripe individuals were captured in every month except October and November. This indicates the possibility of a greatly extended spawning season. Kilby (1955) found very young fish in his collections during all seasons.

This species did not appear to be influenced by the temperature and salinity ranges that were prevalent within the sampling area. This concurs with the findings of other investigators who have recorded temperature and salinity extremes of 16-35.3°C and 0 -58.6°/oo (Dahlberg, 1972; Mountain, 1972; Renfro, 1961; Tabb and Manning, 1961).

Trachinotus falcatus (Linnaeus)
Permit
Number collected: 114
Size range: 15-410mm
Temperature range: 18-33°C
Salinity range: 22-25.5°/oo

T. falcatus are seasonally common in the Big Bend and Tampa Bay areas. Springer and Woodburn collected 226 individuals between November and December, 1957, and in July through December, 1958. All but 4 of the 114 individuals captured during our study were collected between July and November, 1976.

Reid (1954) implied that this species is rare throughout its known range. The findings of Finucane (1969), Springer and Woodburn (1960), and of this study clearly refutes this statement.

Hundreds of _T. falcatus_ were caught by local fishermen in the vicinity of the warm water discharge during February, 1977. These findings were obtained by personal observation and by the results of a creel census that was taken in the Big Bend area. Unseasonably cold weather had penetrated the Tampa Bay area at this time. The fish were undoubtedly attracted to the warm water discharge.

Previous studies (Phillips, 1976a) revealed that _T. falcatus_ has been consistently captured in the Big Bend area since 1970.

The size range of individuals collected in July, 1976 was 26-71 mm. This same year class was represented in the September, 1976 collection. Size range at this time was 67-84 mm. Springer and Woodburn (1960) also noted a rapid growth rate for individuals of this species. They found that individuals ranging in size from 8.2 to 19.8mm in June, increased to 63.6 to 109.6 the following November.

The presence of another year class was also noted in September, 1976, since 9 specimens ranging in size from 143 to 160mm were also captured that month.

Young individuals were again captured in October and November, 1976. This indicates that two spawning periods occurred, or that this species exhibits an extended spawning season. Similar results and conclusions are given by Finucane (1969).

Eucinostomus argenteus Baird and Girard
Spotfin mojarra
Number collected: 5541
Size range: 11-105mm
Temperature range: 14-34.5°C
Salinity range: 18-29 ‰

Peak abundance levels of *E. argenteus* occurred between September and December, 1976. Young individuals (SL $\leq$ 20mm) appeared in the August, September, November and December, 1976 seine catches, and in the February, 1977 collection.

Kilby (1955) felt that only the young of this species made any appreciable use of marshes or inshore waters of the Gulf, since very few of the fish that he collected were over 50mm. As evidenced by the growth progression table for this species (Table 8.5), a considerable number of the *E. argenteus* that we collected were over 50mm, and were utilizing the inshore waters of the bay. Perhaps habitat availability and selectivity (preference) influence the distribution of this species between different study sites.

Kilby (1955) felt that the adults spawn in the Gulf and that the young migrate to inshore waters. We were not able to detect where spawning occurred. Abundance levels of this species steadily declined from November, 1976 to February, 1977, which may have indicated a spawning migration toward the Gulf.

Table 8.5. Growth progression of *Eucinostomus argenteus* captured by seine between January, 1976 and March, 1977.

Mid Class (mm)	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
11									1						
14												2			
17									6		5	2			
20		1						1	13		10	4			
23		2						19	11	2	15	16	4		
26		2	1					24	13	6	10	35	28	2	
29			3			9		12	18	20	13	39	21		1
32		1	9			13	1	27	41	40	30	21	7		2
35		1	10			5	2	24	27	48	22	29	2		8
38		2	15	1		4	8	21	14	43	33	28	1		9
41			15	3		13	19	25	17	44	43	27	2	1	12
44			13	4		22	21	17	29	36	34	26	1		12
47		1	9	3	1	21	29	22	30	21	48	26	1		14
50		1	9	1	1	23	13	25	25	23	42	12	3		16
53			11	5	11	16	4	13	39	8	34	10	5		5
56			6	2	17	8	1	2	25	9	23	10	2		
59			13	6	15		2	1	38	3	9	6	1		3
62			11	2	20	1	1	1	31	4	5	2			1
65			7	1	17	1		3	22	3	3				1
68			5		25	3	1	1	20	5	5				
71			5	1	20	2		6	8		1				
74			4	1	18	1		4	24	5	2				
77			2	1	13	2	1	2	24	6	3				
80			2		18	4	3	6	41	10	2				
83			1	2	9	3	4	2	26	7	4				
86			1		8	1	2	2	36	3	3				
89				1	6		6		17	5					
92					4	1	6		9	7	2				
95				1	5		2		8	6					
98				1	1	2			2	7	1				2
101			1		1		2		3	2	1				
104									1	2					
107															
110															
TOTALS	0	11	152	37	210	160	128	260	619	376	403	295	78	3	86

Eucinostomus gula (Quoy and Gainard)
Silver jenny
Number collected: 2451
Size range: 31-100mm
Temperature range: 15-34.5°C
Salinity range: 18-29°/oo

Peak abundance levels of this species were noted in September through November, 1976. Relative abundance levels were low in the Big Bend area during the winter and spring. The fish may have migrated to the Gulf during this time to spawn. This species disappeared from Kilby's (1955) catches by December. Springer and Woodburn (1960) noted that *E. gula* populations moved from Tampa Bay to Boca Ciega bay as winter approached.

Other investigators have captured *E. gula* at temperatures between 12.8 and 33.6°C and salinities between 2.0 and 37.9 °/oo (Springer and McErlean, 1962; Springer and Woodburn, 1960; Kilby, 1955).

Temperature and salinity did not appear to be a limiting factor in the distribution of this species in the Big Bend area.

Lagodon rhomboides (Linnaeus)
Pinfish
Number collected: 1465
Size range: 16-136mm
Temperature range: 18-34.5°C
Salinity range: 22-29°/oo

Young specimens of *L. rhomboides* first appeared in the seine catches in February and March, 1976, and again in

March, 1977. This corresponds to the winter spawning period suggested by Springer and Woodburn (1960) and Reid (1954). Phillips (pers. comm.) captured young specimens (10-15mm) in January and February, 1976 and 1977. A growth progression outline is presented in Table 8.6.

The limited number of individuals collected after the September seine collection was probably indicative of a spawning migration to the Gulf.

Most specimens were found in shallow, sandy areas. This supports the findings of Springer and Woodburn (1960) who found _L. rhomboides_ to be a common inhabitant of such areas. Reid (1954) found that this species was poorly represented in areas devoid by vegetation.

L. rhomboides have been captured in areas exhibiting a wide range of temperature and salinity values (10.0-35.3°C; 0.8-37.9 °/oo) (Turner and Johnson, 1973; Mountain, 1972; Springer and McErlean, 1972; Springer and Woodburn, 1960; Kilby, 1955; Reid, 1954).

Leiostomus xanthurus Lacépède
Spot
Number collected: 1035
Size range: 16-104mm
Temperature range: 14-27.5°C
Salinity range: 20-29°/oo

This species was first collected in the February, 1976 sample, and was present in the seine catches through May, 1976. Young specimens were present in the catch in February and

Table 8.6. Growth progression of *Lagodon rhomboides* captured by seine between January, 1976 and March, 1977.

Mid Class (mm)	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
17		3	2												1
20		17	10												21
23		29													40
26		24	22												25
29		19	59	12											26
32		7	38	25			1								7
35		1	4	30	1										3
38			2	38	1										
41				55	1										
44				43	7										
47				23	14										
50				6	35										
53					34	6	1	1							
56					41	11									
59				1	37	10	1	1							
62					21	18	9						1		
65					14	14	18	7							
68					7	14	32	1					1		
71					2	12	21	3							
74					2	7	31	5							
77						4	12	7							
80					1		24	4	2						
83							22	3	1						
86							13	3	1						
89							16	2	2						
92						2	3		3						
98							2		2						
101							2	1	6	1					
104									1						
107									1						
110									2						
113									1						
119									2						
125									1						
128								1							
137								1							
TOTALS	0	100	137	237	218	98	215	41	27	1	0	0	2	0	105

March of both 1976 and 1977. The presence of young L. xanthurus at this time of year supports the findings of other investigators (Springer and Woodburn, 1960; Reid, 1954; Kilby, 1955; Gunter, 1938).

Rapid growth rates have been indicated for this species (Kilby, 1955; Reid, 1954; Gunter, 1938). Kilby (1955) determined that this species moves out of marsh areas once it attains a length of about 80mm. As evidenced by the growth progression in Table 8.7, most individuals would be 80mm or larger by June, which corresponds to the time that they were absent from the seine catches. It is conceivable that this species moved from the shoreline areas into the deeper waters of the bay.

In the Tampa Bay area, the adult L. xanthurus probably migrate to the Gulf (where spawning occurs) during the winter and early spring (Springer and Woodburn, 1960).

Menticirrhus saxatilis (Block and Schneider)
Northern kingfish
Number collected: 243
Size range: 15-137mm
Temperature range: 16-31.5°C
Salinity range: 20-27°/oo

This species was formerly referred to as M. focaliger. Irwin (1970) indicated that this was not a valid species. Phillips (1976b) provided a brief account of this name change.

Peak abundance levels of this species occurred in the

Table 8.7. Growth progression of <u>Leiostomus</u> <u>xanthurus</u> captured by seine between January, 1976 and March, 1976.

Mid Class (mm)	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
17														12	
20														6	1
23		1	2												1
26		2	5												8
29			5												18
32			21												41
35			2												39
38				3											31
41				2											16
44				18											11
47				26											16
50				20											9
53				5	1										14
56				4	2										1
59				2	5										1
62				1	10										
65					11										
68					12										
71					10										
74					12										
77					11										
80					20										
83					19										
86					18										
89					11										
92					5										
95					4										
98					3										
101					2										
104					2										
TOTALS	0	3	35	81	157	0	0	0	0	0	0	0	0	18	207

seine catches between May and August, 1976. The young of this species were present in August, September, November and December, 1976. This indicates a spring and summer breeding season in the Big Bend area (Phillips, 1976b, Phillips, 1977).

Springer and Woodburn (1960) noted the presence of this species most often in areas where the salinity was above 25°/oo. In the Big Bend area, this species was most abundant at the Pine Key station (SB-14) between May and August, 1976. Salinities at this station ranged from 27°/oo in May to 22.5 °/oo in August.

Mugil cephalus Linnaeus
Striped mullet
Number collected: 3005
Size range: 15-360mm
Temperature range: 12-34°C
Salinity range: 19-29°/oo

Striped mullet are important commercial species in the Tampa Bay area.

Individuals of this species were captured by seine during each sampling month. Young M. cephalus first appeared in the seine catches in January, 1976 and again in November, 1976. This indicates a late fall and/or early winter spawning season. Springer and Woodburn (1960) assumed that spawning occurs in the Gulf from October to December.

The young apparently migrate into shallow protected areas and utilize them as nursery grounds and areas of refuge. During the summer and fall months, or when a size of 60-100mm is attained, this species tends to "scatter out" (Anderson, 1958; Kilby, 1955). This effect was reflected by decreased catches of this species during these months. Adults were most abundant in the Big Bend area between May and November, 1976. While we captured many adults over 100mm, many more were able to escape simply by jumping over the net.

Springer and Woodburn (1960) presented an informative discussion of M. cephalus activity in the Tampa Bay area. They noted that a migration toward the Gulf occurs in the fall. This phenomenon would explain the relative paucity of adults in the area during this period.

Striped mullet have been captured in areas exhibiting wide ranges of temperature and salinity. Therefore, it is doubtful that these factors would influence the distribution of the young or adults of this species.

Melongena corona Gmelin
Crown conch
Number collected: 385
Size range: 10-113 mm
Temperature range: 12-34°C
Salinity range: 19-29°/oo

M. corona was the most abundant macroinvertebrate captured by seine during this study. This species was concentrated primarily on the mud flats of the embayment station (SB-10). Dragovich and Kelly (1964) noted that species was abundant on mud flats of Old Tampa, Hillsborough, and Boca Ciega Bays.

Young of this species were captured in May and June, 1976; and in September, 1976 through February, 1977. Peak abundance occurred between September and December.

Penaeus duorarum Burkenroad
Pink shrimp
Number collected: 41
Size range (total length): 28-80mm
Temperature range: 18-34.5°C
Salinity range: 22-26 °/oo

This species constitutes an important part of the shrimp industry in the Tampa Bay area.

Relatively few individuals of this species were captured during this sampling period. This was probably due, in part, to gear selectivity and the burrowing habits of this species during the daylight hours (Wickham and Minkler, 1975).

The results of the meroplankton and impingement sections of this report confirm the belief that this species is relatively abundant in this area. Copeland and Bechtel (1974) indicated that this species exhibits a preference for areas with a temperature range of 20-35°C and a salinity range of 20-36°/oo.

Callinectes sapidus Rathburn
Blue crab
Number collected: 57
Size range (carapace width): 9-182mm
Temperature range: 15-34°C
Salinity range: 22-27°/oo

Blue crabs comprise a large percentage of the commercial fishing industry on Tampa Bay.

Individuals of this species were captured by seine in all months, except February, 1977. Dragovich and Kelly (1964) collected this species throughout Tampa Bay during their entire investigation (August 1961 to August 1962). Almost half (21) of the total number that were collected in the Big Bend area, were caught at the embayment station (SB-10).

Most spawning occurs in the spring and summer months (Oesterling, 1976). The adults migrate to the low salinity estuaries to molt and mate (Oesterling, 1976). The young blue crabs utilize protected estuarine waters as nursery areas.

Blue crabs can apparently tolerate wide ranges of temperature and salinity. Copeland and Bechtel (1974) found that optimum catches of this species occurred in water temperatures between 10 and 35°C; and salinity ranges between 0 and 27°/oo.

Relative Abundance and Distribution

Between January, 1976 and March, 1977, a total of 61,273 fishes (56 species; 32 families) and 646 macro-invertebrates (21 species) were captured in 180 seine hauls. The number of fishes and macroinvertebrates captured at each station is listed below.

Station	Total Number of Fishes	Total Number of Macroinvertebrates	% of Total Catch
SB-12	6,787	87	11.1
SB-5	4,388	34	7.1
SB-14	3,352	102	5.6
SB-10	22,981	350	37.7
SB-11	11,554	11	18.7
SB-13	12,211	62	19.8
TOTALS	61,273	646	100.0

The inshore stations (SB-10; SB-11; SB-13) accounted for 76.2% of the total catch. Macroinvertebrates were most abundant at SB-10. Fishes were most abundant at station SB-10 and least abundant at SB-14. Fewest macroinvertebrates were captured at SB-11.

Seasonal peaks in abundance were noted at most of the stations. These peaks generally occurred during the spring and fall months. The lowest abundance levels occurred during the winter months.

Relative abundance values were plotted against temperature and salinity values for each station over the fifteen month period. This information is presented in Figures 8.3 and 8.4.

Peak abundance at station SB-12 (thermally altered) occurred between December, 1976 and February, 1977. The average water temperature at this station was higher than at any other station during this same period. Since upward trends in abundance were not noted at any other station

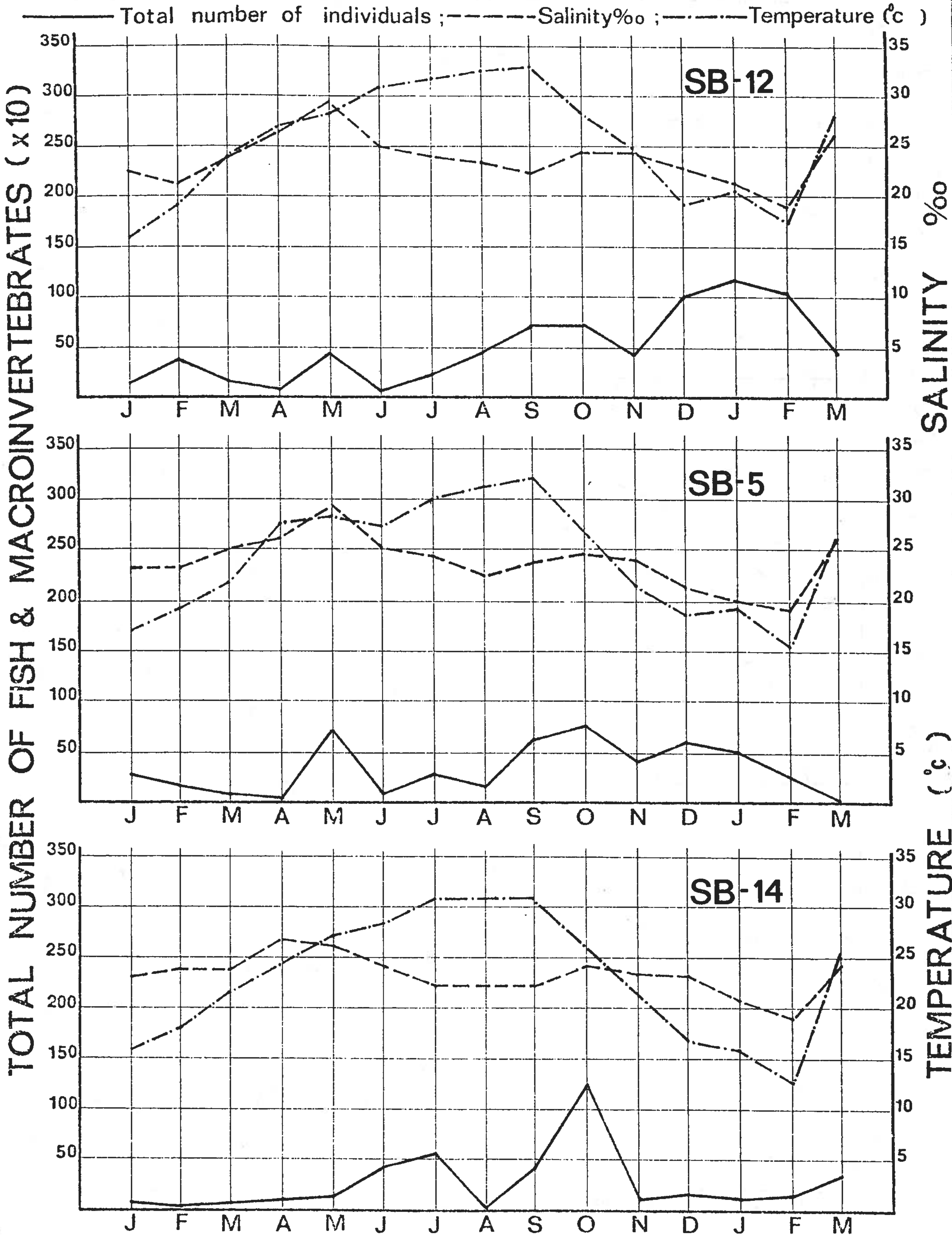


Figure 8.3. Temperature and salinity values, and total number of fish and macroinvertebrates for Stations SB-12, SB-5, and SB-14.

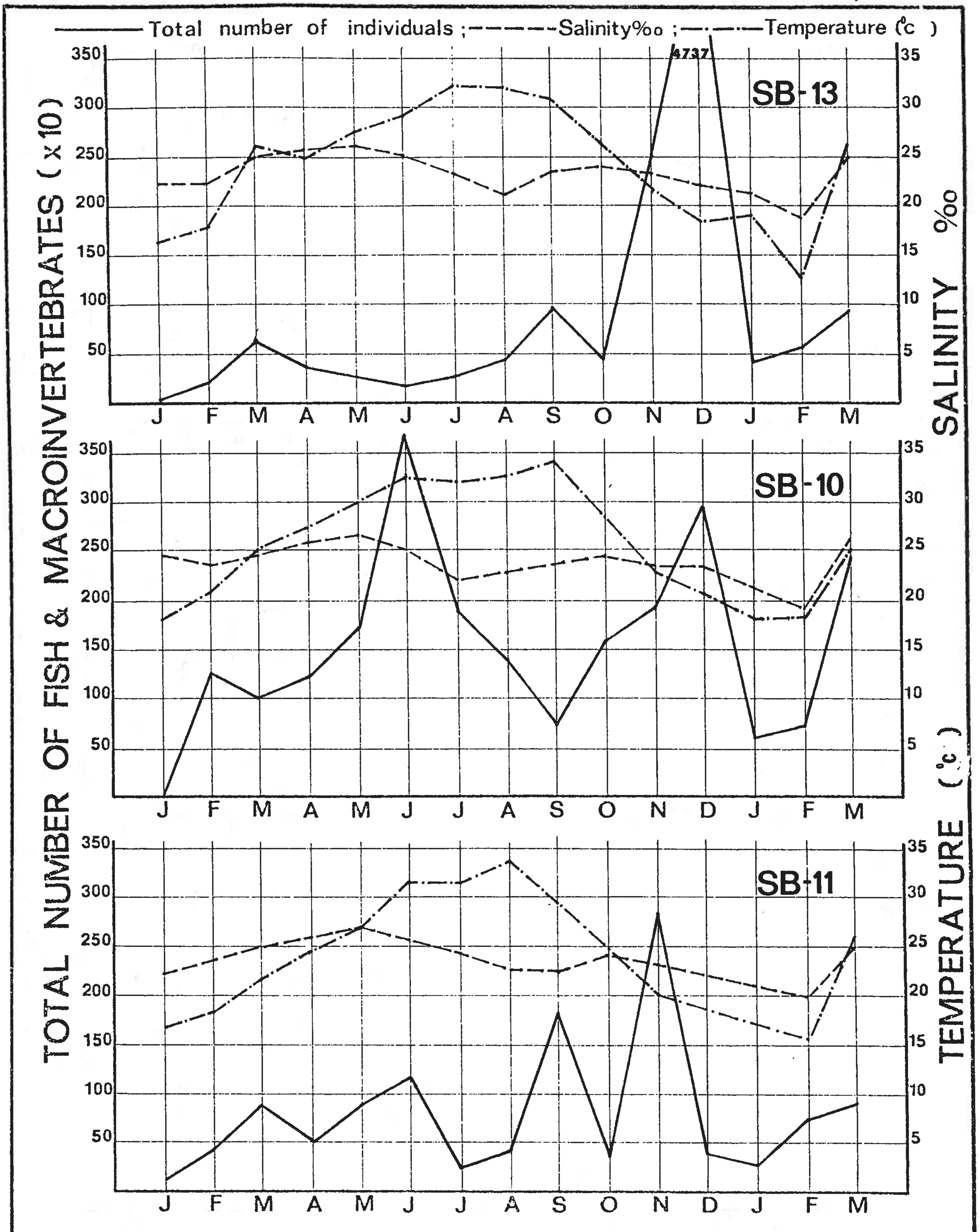


Figure 8.4. Temperature and salinity values, and total number of fish and macroinvertebrates for Stations SB-13, SB-10, and SB-11.

during this time (December - February), it is possible that fishes were attracted to this area (SB-12) because of the presence of the thermal effluent.

Depending on the season, most seine catches were dominated by 2 to 6 species per month. Throughout the course of this study, _Menidia beryllina_ (tidewater silverside) and _Fundulus similis_ (longnose killifish) were usually the two numerically dominant species.

Numerical dominance by a few species is often noted in ecological studies (Livingston, 1976; Gallaway and Strawn, 1975; Dahlberg and Odum, 1970). Changes in numerical dominance are criteria on which impact assessments can be based. If certain opportunistic species consistently increase in abundance over a period of time, it may indicate the deterioration of an environment. Bechtel and Copeland (1970) indicated that this was occurring in a stressed area in Galveston Bay, Texas. This phenomenon does not appear to be occurring in the Big Bend area, since most changes in numerical dominance and distribution can be attributed to natural seasonal variations rather than to a deteriorating environment.

Tables which outline the abundance, dominance, and distribution of the species that were caught by seine each quarter, have been presented in previous reports (Comp and Morris, 1976; Comp, 1976; Comp, 1977a; Comp, 1977b), and in TECO (1977).

Stations SB-5 (non-thermal) and SB-12 (within the thermal plume boundaries) are both sand beach stations with similar sloping shorelines. Throughout the course of this study the average water temperature at SB-5 was slightly lower than the average water temperature at SB-12. A t-test indicated that there was a significant difference (α=.05) in the water temperature between these two stations. However, this same test indicated that there was not a significant difference (α=.05) between the number of animals captured at the two stations. From this information, it does not appear that water temperature significantly alters the abundance levels between these two stations.

Bioindices and Statistical Analyses

The Shannon-Weaver (1963) index of diversity is often used in ecological studies as a basis for determining general community structure or environmental quality (Livingston, 1976; Subrahmanyam and Drake, 1975; Livingston, 1975; McErlean et al., 1973; Bechtel and Copeland, 1970).

Generally, as the distance from a source of pollution increases, the diversity of a community will also increase. Again, stations SB-5 (non-thermal) and SB-12 (within the thermal plume boundaries) were used as a basis for comparison. Overall, there was not a significant difference

(t-test; α=.05) between the diversity values at the two stations.

Diversity levels plotted with temperature are shown in Figures 8.5 and 8.6. A t-test revealed that seasonal differences in diversity were significant (α=.05) only at station SB-13 (non-thermal).

Diversity values were lowest during the winter months, and highest during the summer months at most stations. Grimes (1971) found that diversity values increased away from the outfall area during the summer and toward the outfall in winter at Crystal River. This trend was not noted during this study.

The highest correlation between water temperature and diversity (r=.66) occurred at station SB-12 (within the thermally plume area). All other stations exhibited low linear correlations between diversity and temperature ($r<.66$).

To further analyze the effects of certain physical parameters on the fishes and macroinvertebrates in the Big Bend area, several multiple regression analyses were performed using temperature, salinity, and one of the following sets of data:

1) number of species for each month (r^2 = .34)

2) total number ($\log_{10}$ transformation) of animals at all the seine stations (r^2 =.13)

3) total number ($\log_{10}$ transformation) of animals captured at the outside seine stations (SB-5,

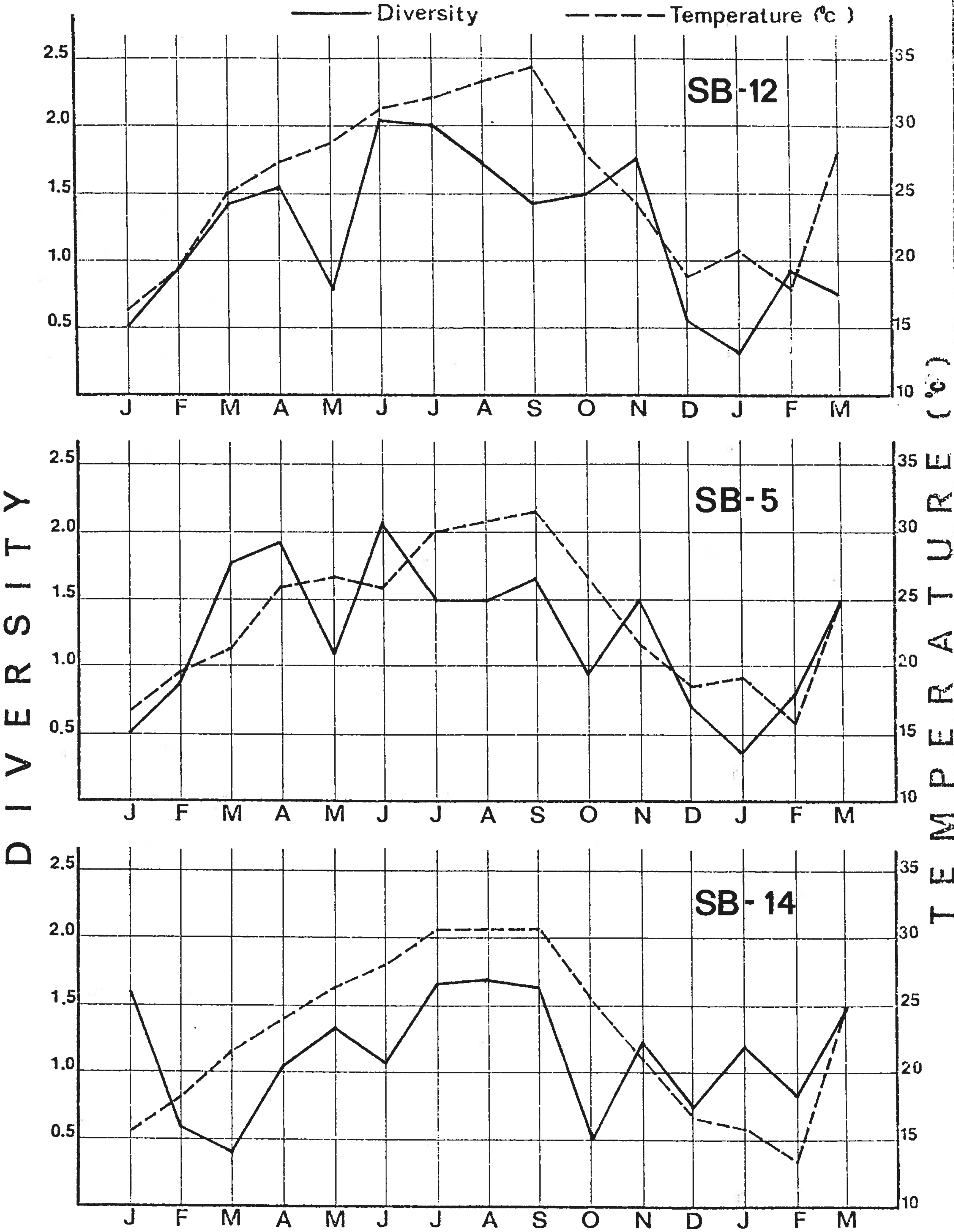


Figure 8.5. Temperature and diversity values at seine stations SB-12, SB-5, and SB-14.

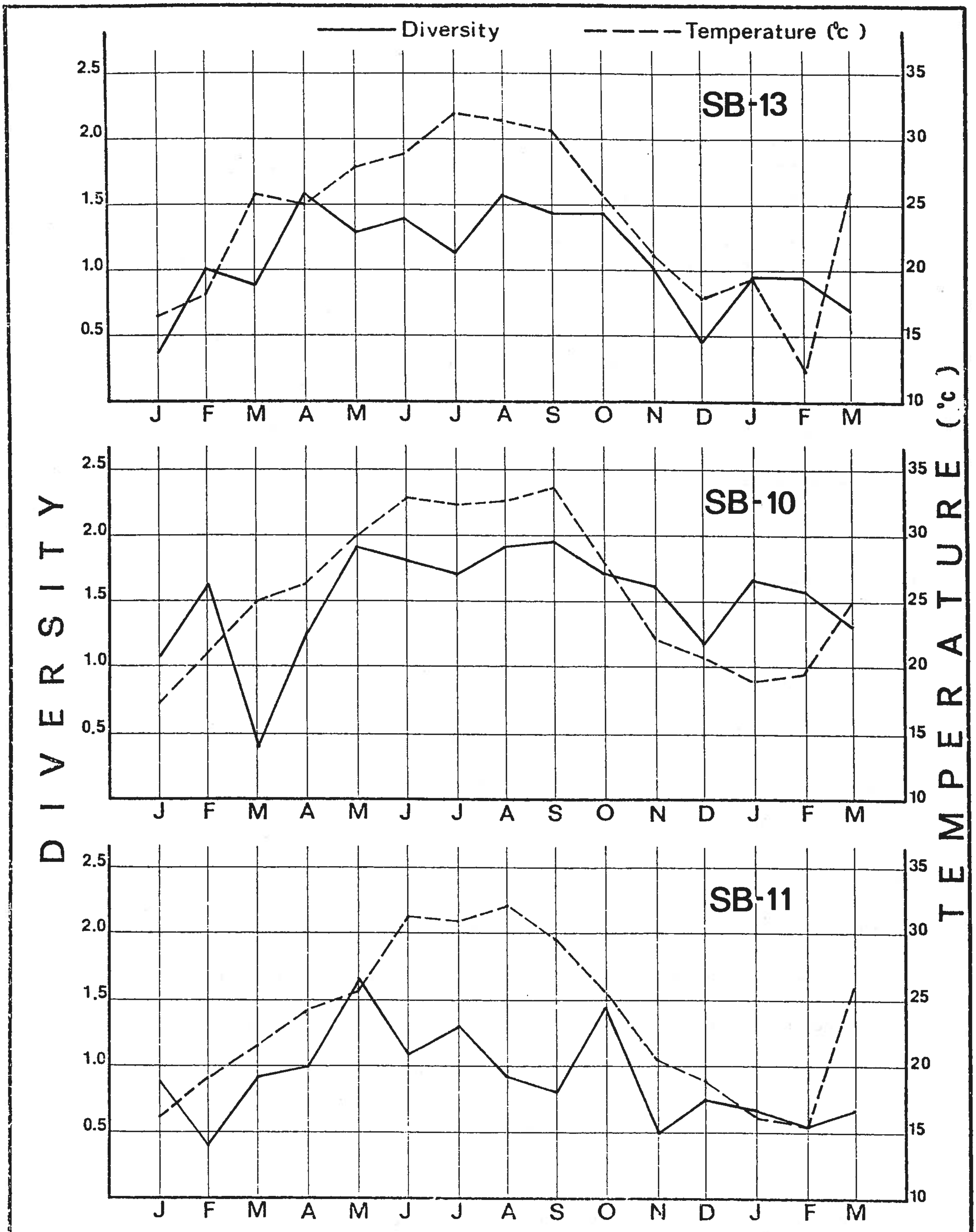


Figure 8.6. Temperature and diversity values at seine stations SB-13, SB-10 and SB-11.

SB-12, SB-14) (r^2 = .22)

4) total number ($\log_{10}$ transformation) of animals captured at the inside seine stations (SB-10, SB-11, SB-13) (r^2 = .1)

5) total number of a commercially important species (M. cephalus, striped mullet) (r^2 = .02)

6) total number of an abundant species (M. beryllina, tidewater silverside) (r^2 = .06). Average temperatures and average salinities were used for this calculation.

The r^2 values remained low. This indicates that most of the differences noted in abundance or distribution can be attributed to a combination of factors other than temperature and salinity.

Species Composition

Another method of assessing the extent of impact due to thermal addition, is to monitor changes in the species composition at the various sampling sites. If the fauna of a particular area is subjected to an intolerable thermal stress, it is conceivable that those species less tolerant of temperature increases would vacate the area.

The number of species that were captured each month at the various stations did not appear to change significantly during the course of this study; nor was the disappearance of any particular species noted.

Figures 8.7 and 8.8 outline the number of species that were captured at each seine station in relation to water temperature and salinity between January, 1976 and March, 1977.

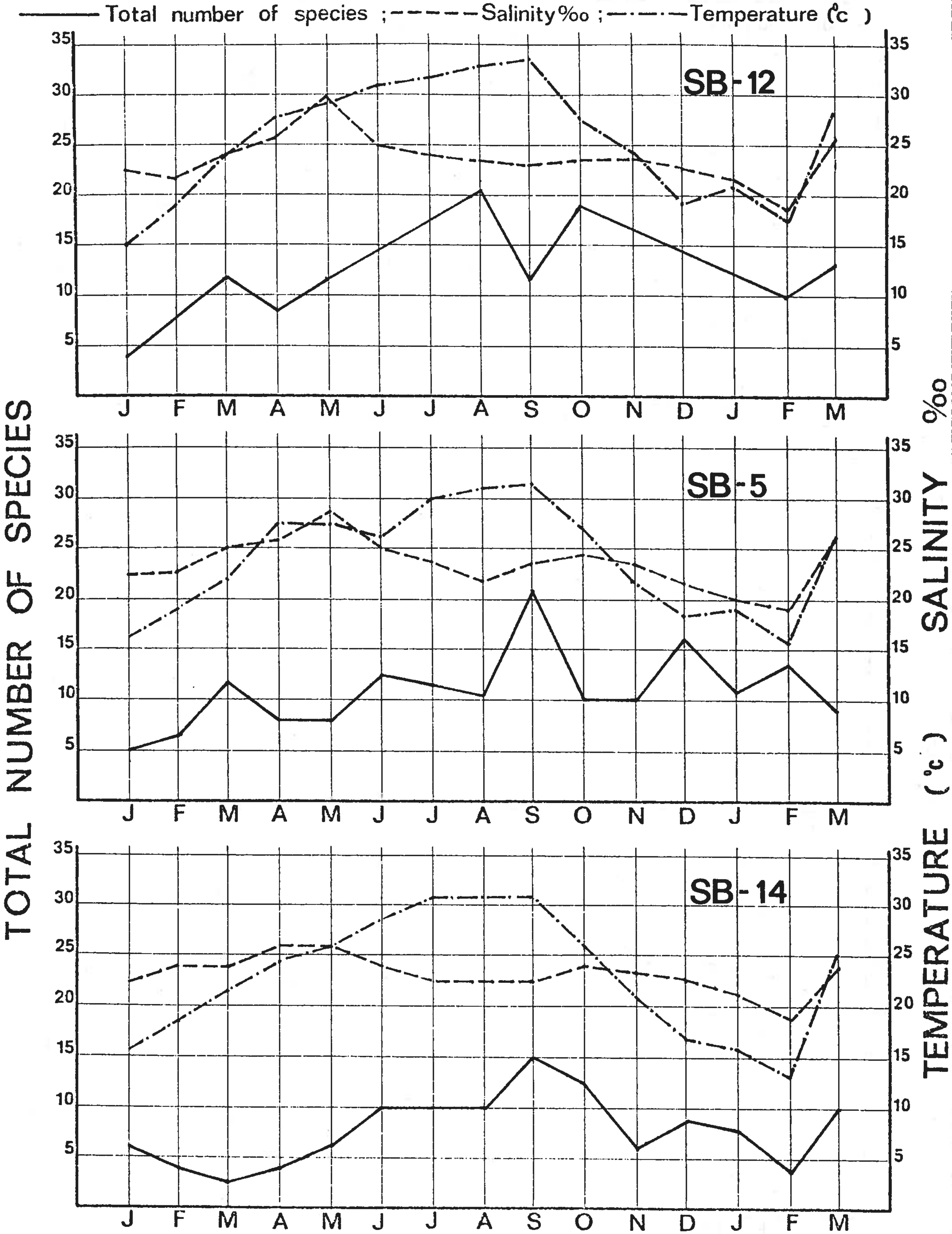


Figure 8.7. Temperature and salinity values, and total number of fish and macroinvertebrate species for Stations SB-12, SB-5, and SB-14.

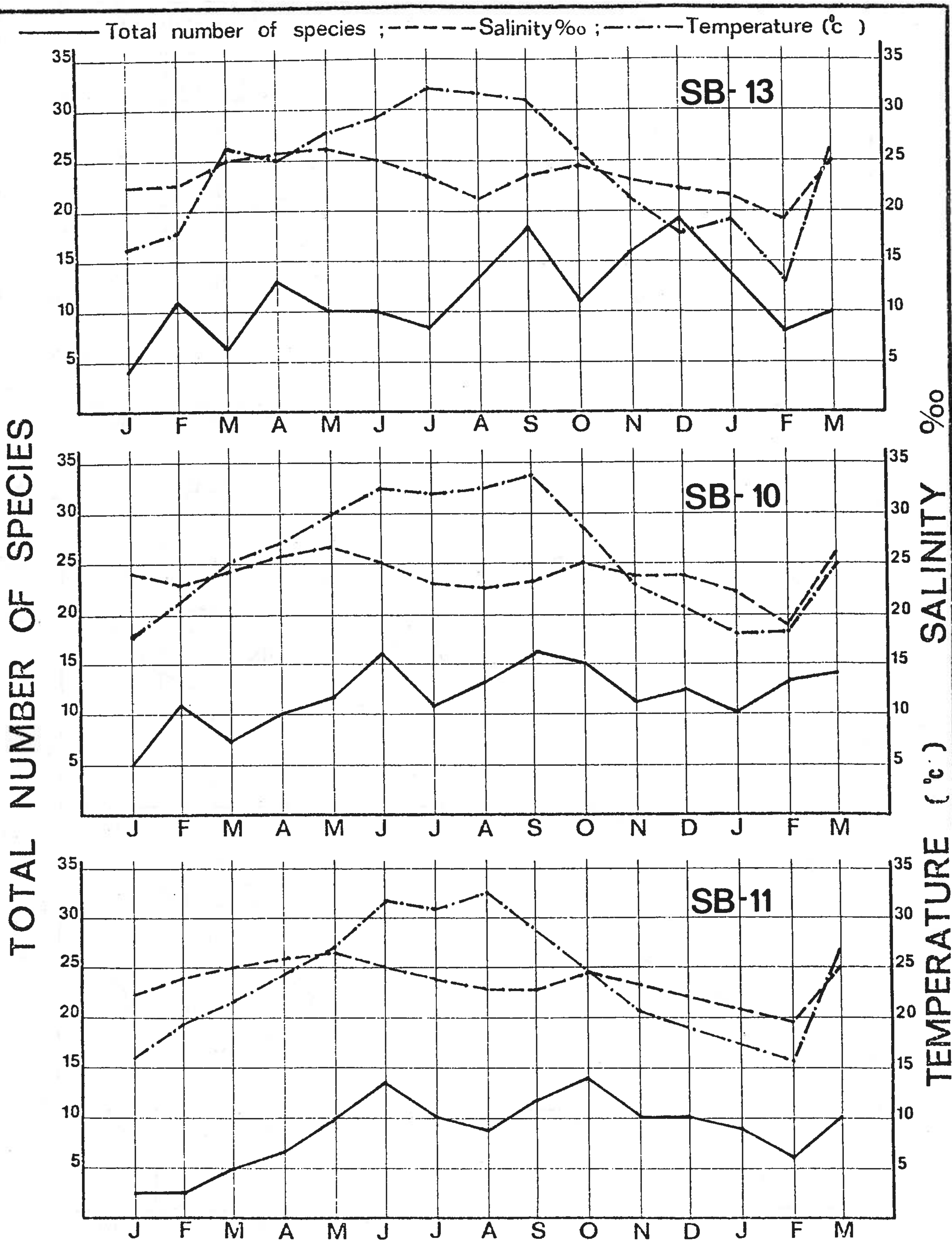


Figure 8.8. Temperature and salinity values, and total number of fish and macroinvertebrate species for Stations SB-13, SB-10, and SB-11.

The total number of species collected at each seine station over the 15 month period (January, 1976 - March, 1977) is outlined below.

Station	Total Number of Species
SB-12	47
SB-5	38
SB-14	14
SB-10	28
SB-11	32
SB-13	42

As shown above, the greatest number of species was found at Station SB-12 (within the thermal plume boundaries).

The Systematic Account, presented earlier, indicated that most of the species in the Big Bend area adhere to the seasonal and migratory trends that were previously elucidated by other investigators. The trends that were used as a basis for comparison with Big Bend data, have been established in areas that were not exposed to the direct effects of pollution or stress. These areas probably supported "natural" populations of marine fishes.

The fishes and macroinvertebrates in the Big Bend area have exhibited patterns of growth, spawning and migration that are similar to those found in unaffected areas.

Tidewater silversides (M. beryllina) and longnose killifish (F. similis) were two of the most dominant species at several of the seine stations. Their numerical dominance and distribution did not appear to be influenced by the thermal effluent, as these species were dispersed throughout the sampling area.

Seasonal changes in species composition appeared to influence community structure more than did the location of the thermal plume.

Faunal Similarity

Morisita's index (Morisita, 1959) was used to compare the faunal similarity at the different stations over a 15 month period. Due to the dynamic nature of fish populations, the validity of the Morisita's index is questionable for use in a fishery study and our results have been interpreted with great caution. Certain seasonal trends were highlighted by this index, and these will be discussed briefly.

Most of the stations exhibited high ($C\lambda > .7$) to moderate ($C\lambda = .5$ to .7) faunal similarities throughout most of the study. Faunal similarity was very low ($C\lambda < .3$) to moderate during the fall months. Changes in species composition and numerical abundance were noted in the fall (probably due to the seasonal influx of large numbers of transient fish species) and this may account for the changes in $C\lambda$ at this time.

Trellis diagrams which outline the similarity of catches at the individual stations over time (15 months), showed similar seasonal patterns. These diagrams are presented in Figures 8.9 through 8.14.

The catch collected at station SB-10 during March, 1977, was dissimilar to most of the catches collected during the other months. This was due to the seasonal influx of young striped mullet (_M. cephalus_) at this station during March. Likewise, the catches made at station SB-11 during November, 1976 and February, 1977 had a very low similarity ($C\lambda < .3$) when they were compared to the catches collected at this station during the other months. Large increases in the number of bay anchovies (_A. mitchilli_) occurred at SB-11 during Nobember, 1976 and February, 1977 thus affecting the similarity values.

The influx of _A. mitchilli_ during November and December, 1976, also affected the faunal similarity at station SB-13. High similarity ($C\lambda = .96$) was noted between the catches made at this station in November and December, 1976. This indicates that the faunal composition at this station was comparable during November and December, 1976, when large numbers of anchovies were present. The catch made at this station during November and December had a low similarity when it was compared to the catches made at this station during the other months, when the anchovies were not present in great numbers.

	1/76	2/76	3/76	4/76	5/76	6/76	7/76	8/76	9/76	10/76	11/76	12/76	1/77	2/77	3/77
1/76															
2/76	.583														
3/76	.692	.970													
4/76	.842	.549	.714												
5/76	.999	.587	.699	.872											
6/76	.863	.633	.795	.921	.869										
7/76	.336	.235	.309	.571	.361	.428									
8/76	.804	.793	.898	.871	.813	.923	.507								
9/76	.178	.150	.174	.313	.182	.198	.818	.369							
10/76	.476	.362	.432	.518	.486	.514	.329	.511	.172						
11/76	.831	.596	.742	.915	.839	.935	.592	.925	.467	.502					
12/76	1.00	.601	.696	.831	.995	.838	.344	.803	.200	.471	.822				
1/77	.997	.591	.680	.811	.991	.817	.324	.782	.185	.460	.799	.999			
2/77	.616	.445	.545	.579	.618	.672	.287	.584	.132	.336	.609	.611	.604		
3/77	.998	.617	.718	.861	.997	.863	.391	.829	.230	.488	.850	.997	.992	.620	

Similarity (Cλ) High (> .7)
Moderate (.5 - .699)
Low (.3 - .499)
Very Low (<.3)

Figure 8.9. Faunal similarity (Morisita's index) of samples collected at SB-12 between January, 1976 and March, 1977.

	1/76	2/76	3/76	4/76	5/76	6/76	7/76	8/76	9/76	10/76	11/76	12/76	1/77	2/77	3/77
1/76															
2/76	.792														
3/76	.828	.772													
4/76	.191	.267	.303												
5/76	.020	.079	.028	.659											
6/76	.598	.464	.705	.853	.443										
7/76	.859	.626	.882	.384	.287	.856									
8/76	.906	.730	.891	.335	.105	.783	.953								
9/76	.570	.469	.596	.366	.262	.562	.685	.788							
10/76	.932	.646	.805	.193	.010	.641	.871	.901	.594						
11/76	.485	.396	.513	.249	.165	.559	.661	.732	.860	.512					
12/76	.982	.675	.804	.176	.025	.611	.882	.915	.617	.938	.528				
1/77	.982	.667	.762	.156	.006	.569	.840	.871	.548	.920	.467	.993			
2/77	.989	.718	.824	.179	.009	.616	.878	.912	.579	.937	.493	.993	.986		
3/77	.520	.493	.881	.312	.126	.514	.663	.572	.385	.509	.329	.513	.477	.516	

Similarity (Cλ) High (> .7)
Moderate (.5 - .699)
Low (.3 - .499)
Very Low (<.3)

Figure 8.10. Faunal similarity (Morisita's index) of samples collected at SB-5 between January, 1976 and March, 1977.

	1/76	2/76	3/76	4/76	5/76	6/76	7/76	8/76	9/76	10/76	11/76	12/76	1/77	2/77	3/77
1/76															
2/76	.718														
3/76	.631	.986													
4/76	.649	.539	.583												
5/76	.532	.819	.669	.397											
6/76	.137	.214	.222	.107	.204										
7/76	.098	.178	.116	.073	.400	.359									
8/76	.438	.595	.431	.268	.900	.297	.642								
9/76	.153	.189	.182	.114	.214	.401	.668	.438							
10/76	.012	.009	.009	.006	.010	.027	.036	.024	.429						
11/76	.389	.551	.509	.289	.529	.916	.435	.563	.476	.027					
12/76	.652	.995	.990	.540	.698	.230	.193	.491	.279	.017	.535				
1/77	.771	.910	.898	.812	.675	.315	.156	.483	.234	.011	.604	.895			
2/77	.755	.362	.279	.167	.198	.098	.044	.212	.069	.023	.176	.298	.266		
3/77	.574	.239	.177	.135	.148	.049	.026	.160	.131	.182	.106	.193	.195	.630	

Similarity (Cλ) High (> .7)
Moderate (.5 - .699)
Low (.3 - .499)
Very Low (< .3)

Figure 8.11. Faunal similarity (Morisita's index) of samples collected at SB-14 between January, 1976 and March, 1977.

	1/76	2/76	3/76	4/76	5/76	6/76	7/76	8/76	9/76	10/76	11/76	12/76	1/77	2/77	3/77
1/76															
2/76	.345														
3/76	.874	.150													
4/76	.240	.950	.028												
5/76	.901	.487	.653	.379											
6/76	.524	.928	.274	.858	.660										
7/76	.505	.347	.180	.330	.472	.582									
8/76	.513	.643	.201	.570	.578	.818	.890								
9/76	.585	.736	.412	.643	.772	.853	.363	.636							
10/76	.278	.235	.207	.172	.497	.423	.328	.404	.652						
11/76	.513	.910	.306	.862	.661	.968	.459	.722	.914	.507					
12/76	.796	.184	.778	.066	.796	.397	.261	.311	.659	.694	.472				
1/77	.446	.626	.175	.526	.509	.768	.807	.925	.570	.485	.693	.317			
2/77	.288	.563	.033	.549	.471	.475	.283	.392	.319	.130	.412	.050	.394		
3/77	.196	.183	.033	.208	.366	.099	.048	.065	.074	.061	.083	.047	.066	.811	

Similarity ($C\lambda$) High ($>.7$)
Moderate (.5 - .699)
Low (.3 - .499)
Very Low ($<.3$)

Figure 8.12. Faunal similarity (Morisita's index) of samples collected at SB-10 between January, 1976 and March, 1977.

	1/76	2/76	3/76	4/76	5/76	6/76	7/76	8/76	9/76	10/76	11/76	12/76	1/77	2/77	3/77
1/76															
2/76	.965														
3/76	.022	.179													
4/76	.163	.375	.508												
5/76	.875	.972	.345	.499											
6/76	.752	.800	.284	.419	.834										
7/76	.936	.948	.149	.231	.916	.802									
8/76	.631	.704	.627	.282	.796	.762	.766								
9/76	.463	.516	.487	.227	.586	.615	.713	.806							
10/76	.069	.101	.361	.091	.155	.178	.355	.428	.848						
11/76	.079	.090	.148	.043	.107	.105	.129	.171	.198	.340					
12/76	.044	.045	.035	.013	.045	.041	.049	.051	.048	.188	.964				
1/77	.970	.951	.037	.181	.881	.766	.934	.674	.487	.081	.082	.043			
2/77	.949	.937	.027	.179	.878	.763	.928	.683	.484	.079	.079	.042	.991		
3/77	.999	.981	.059	.251	.905	.767	.943	.641	.479	.085	.081	.044	.972	.953	

Similarity ($C\lambda$) High (> .7)
Moderate (.5 - .699)
Low (.3 - .499)
Very Low (< .3)

Figure 8.13. Faunal similarity (Morisita's index) of samples collected at SB-13 between January, 1976 and March, 1977.

	1/76	2/76	3/76	4/76	5/76	6/76	7/76	8/76	9/76	10/76	11/76	12/76	1/77	2/77	3/77
1/76															
2/76	.416														
3/76	.313	.691													
4/76	.404	.903	.685												
5/76	.096	.193	.569	.454											
6/76	.410	.912	.903	.912	.443										
7/76	.365	.787	.661	.960	.598	.858									
8/76	.433	.971	.765	.918	.273	.956	.840								
9/76	.427	.981	.729	.913	.236	.939	.818	.993							
10/76	.343	.686	.563	.704	.275	.726	.704	.803	.794						
11/76	.077	.182	.128	.166	.037	.169	.147	.179	.181	.132					
12/76	.467	.977	.717	.910	.230	.928	.827	.991	.981	.746	.180				
1/77	.403	.920	.706	.870	.256	.895	.822	.961	.929	.739	.169	.978			
2/77	.088	.207	.147	.191	.043	.193	.168	.204	.205	.148	1.00	.205	.194		
3/77	.432	.992	.708	.915	.219	.925	.811	.987	.987	.721	.182	.993	.952	.207	

Similarity (Cλ) High (> .7)
Moderate (.5 - .699)
Low (.3 - .499)
Very Low (< .3)

Figure 8.14. Faunal similarity (Morisita's index) of samples collected at SB-11 between January, 1976 and March, 1977.

While these results are not meant to be conclusive, they do indicate that many of the differences in faunal composition between stations and/or months can be attributed to natural occurrences such as schooling, migration, etc.

Nursery Areas

A variety of locations within the Big Bend area appear to be functioning as nursery grounds for several species. The inshore stations, SB-11, SB-13, and especially SB-10, are the predominant nursery areas.

In early 1976, the sheet pile wall adjacent to the thermal discharge area was extended to the western shore of the embayment. This, in effect, further enclosed the embayment and prevented the effluent from directly entering the embayment at this site. This shielded the inhabitants of the embayment from direct exposure to thermally altered water (excluding, of course, tidal introduction of heated water at the western inlet of the embayment).

Juvenile specimens representing a variety of species were captured in this area (SB-10) throughout the course of this study. Several species (notably striped mullet) were found in a wide range of size classes (juvenile to adult). Growth progressions of some of the species which inhabit this area were presented in the Systematic Account section of this report.

This area is often used concurrently by the juveniles of many different species. The migration of young adults out of the embayment often coincides with the migration of post-larval or juvenile specimens of another species into the embayment.

Young striped mullet (*M. cephalus*) are present at this station between December and June. The young of *Leiostomus xanthurus* (spot) appeared in the embayment in February and March. They remained there until May, when they had attained an average length of 84mm. At this time they apparently migrated from the embayment to the open bay. Young specimens of *Lagodon rhomboides* (pinfish) were captured between February and April, while young *Cyprinodon variegatus* (sheepshead minnow) were present in May and June.

The young of *Eucinostomus argenteus* (spotfin mojarra) inundate this area between August and December. Young longnose killifish (*F. similis*) are present between November and December.

The young of several other species are captured sporadically at SB-10. Not enough data was available to discern the approximate length of time that these individuals utilized this area as a nursery ground.

Young bay anchovies (_A. mitchilli_) were the most prevalent juveniles at stations SB-11 and SB-13. The presence of young _A. mitchilli_ was first noted at SB-11 during November, 1976, and February, 1977; and at SB-13 during October, November and December, 1976. Both locations are very shallow and probably afford protection for the young from larger predators.

Station SB-13 also supported populations of pinfish (_L. rhomboides_) from February through September, 1976. During this time, the average length of the juveniles increased from 25mm to 91mm. The young of this species (average length = 25mm) reappeared at SB-13 in March of 1977. This species apparently migrates to the Gulf or open bay during the fall and winter. The young return to the shallow inshore waters during the spring.

Neither stations SB-11 nor SB-13 are within the boundaries of the thermal plume. Like most shallow stations, the water temperature at both SB-11 and SB-13 is probably regulated by solar heating.

All three of these stations (SB-10, SB-11, and SB-13) are important since they apparently provide a suitable habitat for juveniles of several species. From the data collected during this study, it does not appear that the thermal effluent is exerting a detrimental effect on the juvenile communities that are inhabiting the nursery areas.

The growth progression data, presented earlier, has supported the belief that many species inhabit the nursery areas when they are young, and that they remain in these areas until maturity is reached. The individuals then vacate these areas in response to migratory and/or seasonal drives.

If the nursery areas were experiencing detrimental conditions, the juveniles would avoid the area or they would vacate the areas earlier than they normally would. Trends such as these were not noted in the Big Bend area during the course of this study.

Condition Factor

A condition factor (K) was calculated for 5 selected species (tidewater silverside, *M. beryllina*; rough silverside, *Membras martinica*; longnose killifish, *Fundulus similis*; pinfish, *Lagodon rhomboides*, and striped mullet, *M. cephalus*).

K values have been used as a means of measuring such factors as fatness, gonad development, and suitability of the environment(LeCren, 1951). The purpose of incorporating a condition factor into this study was to determine the difference, if any, in the condition factor of fishes residing within and outside of the thermal plume boundaries.

Since a condition factor is a ratio of length to weight, many factors can lead to the erroneous interpretation of results. These factors include: feeding activity, spawning activity (sexual maturity), and age of the specimens.

Condition factors were calculated for each of the five species (up to 75 individuals of each species per replicate) at each station throughout the course of the study. Only those individuals within 3 size classes (40-49mm; 50-59mm; and 60-69mm) were utilized for calculating K values.

Some of the species selected for condition factor analysis were not sufficiently abundant, in the respective size classes, to allow any obvious trends to be discerned. Sufficient data was available to allow valid comparisons to be made of the individuals of two species, *M. beryllina* and *F. similis*, residing within and outside of the thermal plume.

The condition factor results for these two species are summarized in Tables 8.8 and 8.9 .

Both species exhibited the highest monthly average K values between April and August, 1976. The average values declined after this period.

Several factors, including seasonality, could be expected to affect the K values. An ANOVA, comparing the K values for each of these two species over the seasons, was calculated. For each species, there was a significant difference (α =.05) in the K values between the seasons. However, there

Table 8.8. Annual averages of condition factors (K) for *Menidia beryllina* and *Fundulus similis*.

Species	Station	Annual Average K value for size class 40-49	50-59mm	60-69
M. beryllina	SB-12	1.34	1.37	1.33
	SB-5	1.31	1.31	1.36
	SB-14	*	*	*
	SB-10	1.34	1.27	1.25
	SB-11	1.27	1.28	1.20
	SB-13	1.39	1.37	1.33
F. similis	SB-12	1.74	1.83	1.77
	SB-5	2.11	1.67	1.80
	SB-14	2.19	1.71	1.75
	SB-10	1.75	1.89	1.75
	SB-11	1.77	1.81	1.72
	SB-13	1.86	1.59	1.75

*insufficient data

Table 8.9. Monthly condition factor values (K) for *Menidia beryllina* and *Fundulus similis* at all stations.

	J	F	M	A	M	J	J	A	S	O	N	D
M. beryllina	1.38	1.40	1.20	1.59	1.45	1.57	1.58	1.55	1.36	1.30	1.15	1.10
		J	F	M								
		1.10	1.10	1.16								
F. similis	1.66	1.76	1.65	2.05	2.37	2.26	2.34	2.10	1.70	1.71	1.55	1.52
		J	F	M								
		1.42	1.42	1.69								

was not a significant difference (α =0.5) in the K values for each species, between the different stations over a 15 month period.

A t-test indicated that there was no significant difference (α=.05) between the overall condition factor of M. beryllina and F. similis at station SB-5 (non-thermal) and at SB-12 (within the thermal plume boundaries).

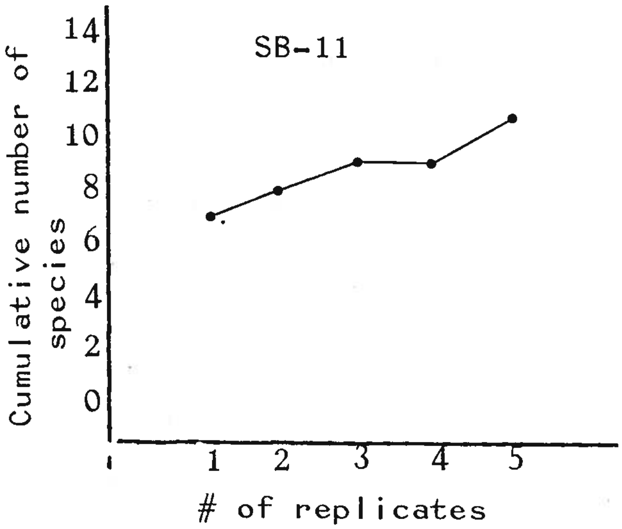
Replicate Sampling

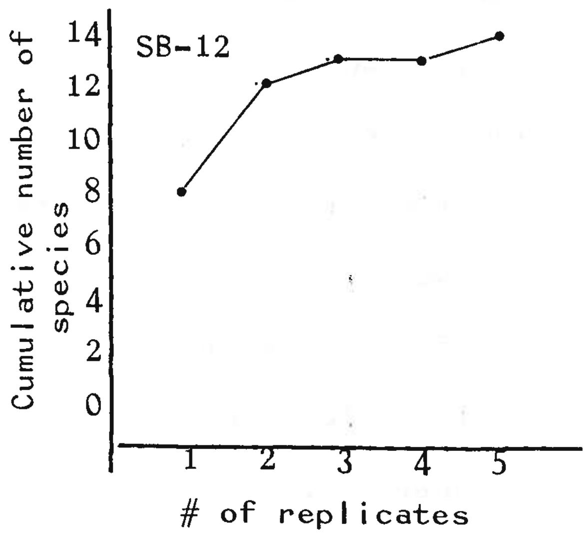
In April, 1977, a series of 5 consecutive replicate seine hauls were taken at station SB-11. The following day, 5 consecutive replicate hauls were made at station SB-12. The purpose of this survey was to acquire additional information on the sampling efficiency of the seine. Since this procedure was implemented only once at each of 2 stations, the following results are not conclusive.

Species saturation curves for the seine replicates (Figure 8.15) indicate a "levelling out" after the second replicate haul at SB-12. This did not appear to occur at SB-11. The 3 additional replicates (after the usual 2) at SB-12 accounted for 2 additional species; while 3 additional replicates at SB-11 accounted for 3 additional species.

It appears that the numerically dominant species were represented within the first 2 hauls, since the additional species that were captured after 2 hauls were usually represented by 2 or fewer individuals.

Figure 8.15 Species saturation curves for replicate seine hauls.





<u>Trawl</u>

Physical and Chemical Parameters

The quarterly values of all parameters collected during trawl sampling have been presented in previous reports (Comp, 1976; Comp, 1977a; Comp, 1977b) and in Teco, 1977.

The averages and ranges of the temperature and salinity values are outlined below.

Transect	Water Temperature (°C)				Salinity (°/oo)			
	Average		Range		Average		Range	
	Surf.	Bot.	Surf.	Bot.	Surf.	Bot.	Surf.	Bot.
TB-1	27.0	25.1	35-21	34-20.5	22.4	22.3	20-25	20-25
TB-12	24.2	20.0	31-18	30-18	22.2	22.2	20-26	20.5-26
TB-5	23.2	21.1	31-16	30-16	22.0	21.6	20-25	20.5-25
TB-7	22.7	20.1	31.5-16	30-15	22.2	22.3	20-25	21-24
TB-6	22.2	20.0	31-16	29-16	21.9	22.1	20-25	20-25
TB-13	21.8	20.0	30-17	28-16	21.6	21.9	19-25	20-24
TB-4	21.3	19.4	31-16	28-15	21.3	21.9	18.5-24	19.5-24

Although the highest temperature that was recorded during trawling was 35°C at the discharge site, temperatures in this area often exceed 35°C. See the hydrographics section of this report for a list of temperature ranges in the discharge canal.

Water temperature decreased as distance from the point of discharge increased.

From the limited data that was collected during trawl sample collection, it appears that the thermal effluent penetrates at least a portion of the TB-12 transect. Surface water temperature at this station averaged 2.4°C higher than a similar embayment transect (TB-13) that lies outside of the thermal plume boundaries. Average bottom water temperatures were similar at both stations (TB-12 and TB-13). Thermal stratification is apparent at TB-12.

In most cases, the water temperature at the south end of transect TB-12 is lower than at the north end of the transect. Therefore, it is possible that the influence of the thermal effluent is apparent only in the northern portion of the embayment. The area that the effluent permeates is probably governed by wind direction and tidal stage. R. Peekstok (pers. comm.) has determined that thermally altered water penetrates a large portion of the northern embayment during a flood tide.

The reader is referred to the hydrographics section of this report for a more complete explanation of the hydrography of the sampling area.

The number of generating units that were operating when a sample was collected would influence the water temperature along some of the transects. Since trawling occurred infrequently, the collection of physical and chemical data at the trawl stations also occurred infrequently. This limited amount of data made it impossible to discern the temperature rise that can be attributed to each unit. Again, the reader is referred to the hydrographics section of this report for a more detailed explanation.

Relative Abundance and Distribution

Only four sets of trawl data were collected during the course of this study, so abundance and distribution patterns are difficult to discern.

Day trawling accounted for a total of 2,109 fishes (26 families; 34 species) and 383 macroinvertebrates (24 species) in 56 trawl tows. Night trawling in February, 1977, accounted for an additional 4,349 fishes and 247 macroinvertebrates in 14 tows.

Trawl catches, listed in numerical abundance, have been presented in previous reports (Comp, 1976; Comp, 1977a; Comp, 1977b) and in TECO (1977).

As a summary of this information, the following table lists the number of fishes and macroinvertebrates captured (day samples only) along 7 transects between June, 1976 and February, 1977.

Transect	Total Number of Fishes	Total Number of Macroinvertebrates	% of Total Catch
TB-1	75	15	3.6
TB-12	566	25	23.7
TB-5	121	53	7.0
TB-7	482	34	20.7
TB-6	63	19	3.3
TB-13	473	198	26.9
TB-4	329	39	14.8
TOTALS	2,109	383	100%

The presence of large numbers of tunicates (Molgula sp.) in the trawl catch at TB-13 in February may have biased the true macroinvertebrate distribution percentages. The following table outlines fish and macroinvertebrate distribution at the various stations, excluding the number of tunicates that were captured.

Transect	Total Number of Fishes	Total Number of Macroinvertebrates excluding Molgula sp.	% of Total Catch
TB-1	75	15	3.9
TB-12	566	22	25.3
TB-5	121	53	7.5
TB-7	482	34	22.2
TB-6	63	19	3.5
TB-13	473	31	21.7
TB-4	329	39	15.8
TOTALS	2,109	213	

Transects TB-12, TB-7 and TB-13 accounted for the greatest number of fishes in the day samples. Fewest fishes were captured along transects TB-1 and TB-6.

The apparent abundance of macroinvertebrates along transects TB-13 is undoubtedly due to the large numbers of *Molgula* sp. that were captured in February, 1977. Transect TB-13 accounted for only 31 macroinvertebrates, excluding the tunicate, *Molgula* sp.

Disregarding the number of tunicates that were captured, macroinvertebrates were most abundant along transect TB-5 (open bay; within the thermal plume); and least abundant along transect TB-6 (open bay; outside of the thermal plume boundaries).

Transects TB-7 (within the plume) and TB-6 (outside of the plume boundaries) have similar depths, habitats, and location. Transect TB-7 consistently accounted for more organisms that did transect TB-6. The reason for this is not completely understood. It may be that the plume area is attracting the fishes for some reason other than temperature (e.g. food abundance) since the average water temperatures along these two transects are similar.

The trawl catch was generally dominated by one species each quarter. The bay anchovy (*A. mitchilli*) was numerically dominant in 3 of the 4 sampling periods. The pinfish (*L. rhomboides*) was dominant in the February, 1977 sample.

Diversity

An increase in diversity values and/or abundance might be expected as distance from the source of discharge increases if the thermal effluent was exerting a detrimental effect on the marine organisms. This has been shown to occur in previous studies in other areas (Livingston, 1975; Bechtel and Copeland, 1970; Tsai, 1968; Katz and Gaufin, 1953).

The following table lists the diversity values of the trawl catches throughout the sampling period.

Transect	June	September	November	February Day	February Night	Average
TB-1	1.29	0+	1.04	0.68	0.83	0.77
TB-12	0.056	0.29	0.80	1.62	1.34	0.82
TB-5	1.60	0.86	1.13	1.94	0.52	1.21
TB-7	0.85	1.62	1.18	0.50	0.38	0.91
TB-6	1.57	0+	1.15	1.48	1.88	1.22
TB-13	1.56	0.70	1.0	1.40	1.68	1.27
TB-4	0.56	0+	0.94	1.11	1.44	0.81

+insufficient number of species to calculate diversity.

While both stations TB-7 and TB-12 accounted for large numbers of individuals, the average diversity of the catches at these stations was low. This is, undoubtedly, due to the numerical dominance of *A. mitchilli* at these stations.

The lowest average diversity was recorded in the discharge canal (TB-1). Diversity values did not appear to increase as distance from the discharge area increased.

Day Versus Night Trawling

During sample collection in February, 1977, trawl tows were also conducted at night to supplement the day catches.

The number of fishes, macroinvertebrates, and total species captured along the trawl transects in February, 1977 (only) are outlined below.

Transect	Total Number of Fishes		Total Number of Macroinvertebrates		Total Number of Species	
	Day	Night	Day	Night	Day	Night
TB-1	63	183	2	3	7	7
TB-12	61	377	10	85	14	21
TB-5	10	1733	4	9	8	16
TB-7	131	1304	0	5	6	14
TB-6	41	159	3	34(33)+	9	19
TB-13	451	332	188(21)	80(28)	12	17
TB-4	309	261	23	31	12	15

+number of macroinvertebrates that were captured excluding *Molgula* sp.

Several factors were probably responsible for the numerical differences that were noted between the day and night catches. The fishes were, apparently, actively feeding during the night (as evidenced by cursory stomach analysis). Schooling in areas abundant with food may have facilitated the collection of more fishes at night.

Since the trawl is less visible at night, it would be more difficult for fishes and macroinvertebrates to avoid its path.

Crabs and shrimp are usually more active at night, and would, therefore, be more susceptible to capture.

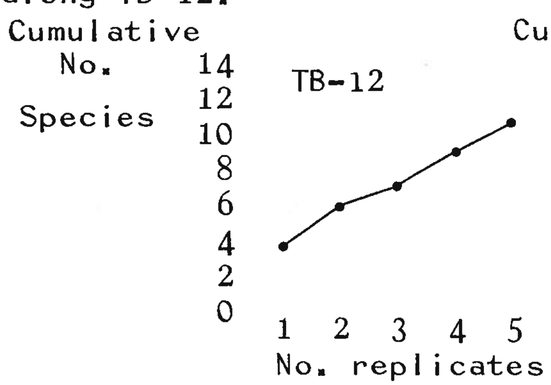
All these factors led to an increase in the number of organisms that were captured by trawling at night.

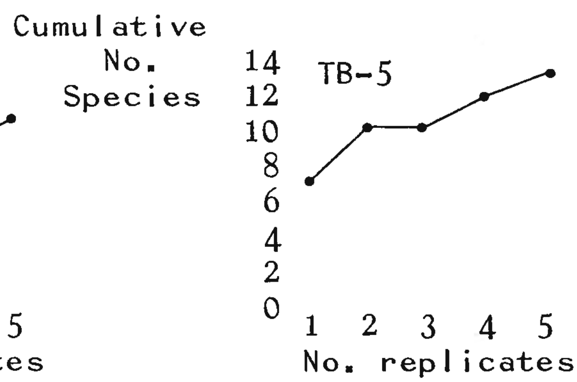
These data also indicate that the abundance of fishes along the trawl transects (especially TB-1) is greater than that which is indicated by the day trawl samples.

Replicate Sampling

In April, 1977, a series of 5 consecutive replicate tows were made along 2 different transects (TB-12 and TB-5). The purpose of this survey was to acquire additional information on the sampling efficiency of the trawl. Since this procedure was only implemented once at each of 2 stations, the following results are not conclusive.

Species saturation curves given below indicate a slight "levelling out" after the second replicate along TB-5, although the curve rises again after the third replicate. This "levelling out" affect was not noted after 5 replicates along TB-12.





The data collected during this survey indicates that, at least the numerically dominant species were captured within the first two replicates, since the additional species that were captured after two hauls were usually represented by two or fewer individuals.

However, the curves do indicate that additional tows would be necessary to achieve species saturation in the samples.

Fisherman Survey

A creel census was initiated at the boat launching ramp which is adjacent to the discharge area at Big Bend. A box containing printed questionnaires was erected at this site. The fishermen were asked to supply us with the following information: number and kinds of fish that were caught, approximate size of the fish; number of hours of fishing; type of boat that was used; general location of fishing; and general comments.

A total of 86 completed forms were returned between April, 1976 and early March, 1977. Unfortunately, repeated vandalism of the questionnaire box interrupted the survey several times, and forced the premature termination of this survey in March, 1977.

While the data collected from this census was not quantitative, it did indicate that the Big Bend area, especially the discharge canal, is heavily fished by both sport and commercial fishermen.

This survey also supported our belief that many species of fish are present in the discharge area, even though these species are poorly represented in our trawl catches in that area. Results of this survey confirmed the presence of substantial numbers of snook (*Centropomus undecimalis*), spotted seatrout (*Cynoscion nebulosus*), redfish (*Sciaenops ocellata*), gray snapper (*Lutjanus griseus*), spadefish (*Chaetodipterus faber*, and black drum (*Pogonias cromis*).

Interviews with local fishermen revealed that fishing is generally poor in the discharge canal during the summer months when peak temperatures in this area (and the bay) are reached. Conversely, the warm water appears to attract many species of fish during the winter, hence fishing activity and catch success increases.

The sport and commercial fishing activity (and success) in the Big Bend area apparently was not reduced as a result of the addition of a third generating unit. Rather, the operation of those units appears to enhance the fishing activity in this area, at least during the winter months.

IMPACT ASSESSMENT

In early May, 1977, a third generating unit became operational at Big Bend. This increased the capacity of this power station from a normal output of 750 megawatts (mw) to 1125 mw. The primary objective of this seine and trawl study was to assess the extent of environmental impact on fishes and macroinvertebrates in the Big Bend area due to the additional thermal effluent produced by the third unit.

When using community structure or population shift studies to assess impact at power plants, pre- and post-operational data should always be collected. These data should include identification of the species that are present within the sampling area; determination of the relative abundance of these species; and determination of the faunal distribution. This allows a basis for comparisons to be made between pre- and post-operational community structures.

Seasonal changes in abundance, distribution and diversity will inevitably occur at each sampling station. Such seasonal changes have been well documented (Cain and Dean, 1976; Subrahmanyam and Drake, 1975; Gallaway and Strawn, 1974; Haedrich and Haedrich, 1974; and Dahlberg and Odum, 1970). It is imperative that the natural seasonality of species within the sampling area be understood, so that erroneous interpretations of changes in community structure or abundance do not occur.

The seasonal data that was collected at Big Bend was compared to the data collected at other sites. These other studies were cited extensively in the Systematic Account section of this report. Once the natural patterns of seasonality are established, unnatural changes resulting from stressed situations are more apparent.

Some baseline data has been collected at Big Bend since 1970 (see page 8-19). However, extensive sampling did not begin until January, 1976, four months prior to the date of operation for Unit 3. Comparisons of the data collected prior to May, 1976 (this includes some of the pre- January 1976 data, and all of the baseline data collected after January, 1976) with the data collected after that date revealed no apparent changes in species composition, distribution, or diversity that could be directly attributed to the discharging of thermal effluent. Most of the differences that were noted were attributed to natural variations due to seasonality.

The occurrence of significant changes in community structure or abundance, as a result of thermal addition, is not a common phenomenon according to many impact analysis.

Gallaway and Strawn (1974) studied the seasonal abundance and distribution of fishes in Galveston Bay, Texas. They concluded that the detrimental effects on the fish fauna were neglibible in the vicinity of a hot water discharge. They found that no significant differences in populations occurred when the power plant output increased from 900 mw to 1,465 mw. Most of the species in that area were abundant in water tempetatures of 33°C to 35°C. Certain species (striped mullet and sand seatrout) were observed in water that was 40°C. Abundance at the seine stations at Big Bend did not appear to decrease as temperatures approached 33°C and above.

Cairns (1976) summarized the findings of investigations implemented at three power stations (Potomac Steam Electric Power Plant at Fredrich, Maryland; Savannah River Plant, Aiken, South Carolina; and Paradise Steam Plant, Kentucky). No effects that could be directly attributed to the thermal discharge were evident at two of the three sites. Effects were noted at the third site (Paradise Steam Plant).

Grimes (1971) found that the diversity of communities increased away from the discharge area during the summer, and toward the discharge during the winter at Crystal River, Florida. He concluded that there was no indication that the heated effluent had eliminated native species or caused any significant changes in abundance.

Other investigators have found that significant effects can result as a consequence of thermal addition. Roessler and Tabb (1974) in a study of Biscayne Bay, Florida, determined that an average temperature increase of 3 or 4°C above ambient summer water temperatures caused serious depletion of the biota in the vicinity (100 acres) of a thermal discharge.

It appears that most effects are site specific and that generalized conclusions or predictions, concerning the possible effects of discharging thermal effluent into aquatic environments, are not feasible.

Insufficient data was collected in the discharge canal at Big Bend (seining was not possible because of the absence of a suitable beach). Hypothetically, if significant differences in abundance and/or community structure were occurring as a result of thermal addition, the effects would be confined to the discharge canal since this area is exposed to a maximum temperature increase.

No significant differences in relative abundance or faunal composition were found between the seine stations during the course of this study. More importantly, the fauna at each seine station exhibited seasonal variations which appeared normal for this region. Actually, the Hillsborough Bay seine stations appear to be removed from the direct influence of the warm water discharge. The temperature of the effluent has cooled considerably by the time it is discharged into Hillsborough Bay. Cooler bay water is mixed with the thermal effluent in the dilution (discharge) canal before this water enters Hillsborough Bay.

Since the area that is most susceptible to the effects of the heated effluent is small (discharge canal), the mobility of fishes will enable them to avoid this area during periods of excessive heating. This avoidance can easily occur without the loss of an irreplaceable ecological niche. The habitat created by the discharge canal does not appear to be vital to the survival of any particular species. Similarly, fishes can easily utilize this warm area during the winter months when ambient bay temperatures decline.

Seine station SB-12 is located close to the point of discharge into Hillsborough Bay. No significant differences in abundance and/or distribution that can be directly attributed to the effluent were found.

Station SB-10 appeared to be the most important station in terms of its function as a nursery area. No detrimental effects, due to the thermal discharge, were apparent in this area.

It can therefore be surmised that overall the discharging of thermal effluent into Hillsborough Bay is eliciting a negligible effect on the indigenous and transient fishes and macroinvertebrates in the Big Bend area.

GENERAL CONCLUSION

No immediate, significant, deleterious effects (except for, possibly, seasonal effects in the discharge canal) on the fish and macroinvertebrate populations in the Big Bend area have been found, using methods as described in this report.

SUMMARY AND CONCLUSIONS

1) Intensive sampling (by trawl and seine) of the fish and macroinvertebrate communities in the vicinity of the Big Bend steam electric station was conducted between January, 1976 and March, 1977.

2) Annual average water temperatures at the seine stations ranged from 22.8°C at station SB-14 (Pine Key) to 25.8°C at station SB-10 (northern embayment).

3) Seining (180 hauls) accounted for a total of 61,272 fishes (56 species; 32 families) and 647 macroinvertebrates (21 species).

4) Station SB-10 (northern embayment) accounted for 37.5% of the fishes and 54.1% of the macroinvertebrates that were captured during the course of this study.

5) The tidewater silverside (Menidia beryllina) was the most abundant fish captured by seine throughout most of the study period.

6) Most changes in numerical dominance and distribution were attributed to natural seasonal variations

rather than to a deteriorating environment.

7) Generally, diversity values were lowest during the winter months, and highest during the summer months at most of the seine stations.

8) There was little correlation between temperature, salinity and: a) the total number of animals captured at each station each month; b) the total number of species captured at each station each month; c) the total number of animals captured at the outside stations (SB-5; SB-12; SB-14); d) the total number of animals captured at the inside stations (SB-10, SB-11, SB-13); e) abundance of a commercially important species (*Mugil cephalus*); and f) abundance of *Menidia beryllina* (average temperature and average salinity values were used for this calculation).

9) The number of species that were captured each month at the various seine stations did not appear to change significantly during the course of this study, nor was the disappearance of any particular species noted.

10) The fishes and macroinvertebrates in the Big Bend area have exhibited patterns of growth, spawning and migration that are similar to those found in unaffected areas.

11) Seasonal changes in species composition appeared to influence community structure more than did the location of the thermal plume.

12) The northern embayment station (SB-10) and, to a lesser extent, stations SB-11 and SB-13 are functioning as nursery areas for a variety of species.

13) The data that was collected between January and May, 1976 (and some of the 1970-1975 baseline data) was compared to the data collected after Unit 3 became operational (May, 1976). These comparisons revealed no significant changes in species composition, distribution or diversity that could be directly attributed to the discharge of thermal effluent.

14) The fauna at each seine station exhibited seasonal variations which appeared normal for the region.

15) Annual average bottom water temperatures along the trawl transects ranged from a high of 25.1°C in the discharge canal (TB-1) to a low of 19.4°C in the intake canal (TB-4). Bottom water temperature in the discharge canal ranged from a high of 34°C in September, 1976 to a low of 20.5°C (during night sampling) in February, 1977.

16) Day trawls (56 tows) accounted for a total of 2,109 fishes (26 families; 34 species) and 383 macroinvertebrates (24 species). Night trawling in February, 1977 accounted for an additional 4,349 fishes and 247 macroinvertebrates in 14 tows.

17) Stations TB-1 (discharge canal) and TB-6 (open bay) accounted for the lowest number of organisms.

18) No significant, immediate deleterious effects (except for, possibly, in the discharge canal during the warm months) on the fish and macroinvertebrate populations in the Big Bend area have been found using methods as described in this report.

LITERATURE CITED

Anderson, W. W. 1958. Larval development, growth and spawning of striped mullet (*Mugil cephalus*) along the south Atlantic coast of the United States. Fish. Bull. 58(44):501-519.

Bailey, R. M. (Chairman). 1970. A list of common and scientific names of fishes. Amer. Fish. Soc. Spec. Publ. 6. 150 p.

Bechtel, T. J. and B. J. Copeland. 1970. Fish species diversity indices as indicators of pollution in Galveston Bay, Texas. Contr. Mar. Sci. 15:103-132.

Cain, R. L. and J. M. Dean. 1976. Annual occurrence, abundance and diversity of fish in a South Carolina intertidal creek. Mar. Biol. 36:369-379.

Cairns, J., Jr. 1976. Heated waste-water effects on aquatic ecosystems. In Thermal Ecology II. G. W. Esck and R. W. McFarlane, eds. Technical Information Center, Springfield, Va. pp. 32-38.

Comp, G. S. 1976. Fish and macroinvertebrate distribution as determined by seine and trawl catches. Chapter 8, pp. 380-431. In Tampa Electric Company, Twenty-seventh quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-fourth quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 440 p.

Comp, G. S. 1977a. Fish and macroinvertebrate distribution as determined by seine and trawl catches. Chapter 8, p. 573-635. In Tampa Electric Company, Twenty-eighth quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-fifth quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 651 p.

Comp, G. S. 1977b. Fish and macroinvertebrate distribution as determined by seine and trawl catches. Chapter 8, p. 590-653. In Tampa Electric Company, Twenty-ninth quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-sixth quarterly report by Conservation Consultants, Inc. R. Garrity, Ed. 666 p.

Comp, G. S. and C. A. Morris. 1976. Macroinvertebrates and fish as sampled by trawls and seines. Chapter 8, p. 429-465. In Tampa Electric Company, Twenty-sixth quarterly report on the Big Bend thermal and ecological surveys. Contains twenty-third quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 469 p.

Copeland, B. J. and T. J. Bechtel. 1974. Some environmental limits of six Gulf Coast estuarine organisms. Contr. Mar. Sci. 18:169-204.

Dahlberg, M. D. 1972. An ecological study of Georgia coastal fishes. Fish. Bull. 70(2):323-353.

Dahlberg, M. D. and E. P. Odum. 1970. Annual cycles of species occurrence, abundance and diversity in Georgia estuarine populations. Amer. Midl. Nat. 83(2): 382-392.

Dragovich, A. and J. A. Kelly, Jr. 1964. Ecological observations of macroinvertebrates in Tampa Bay, Florida, 1961-1962. Bull. Mar. Sci. Gulf and Caribbean. 14(1): 74-102.

Finucane, J. H. 1969. Ecology of the pompano (*Trachinotus carolinus*) and the permit (*T. falcatus*) in Florida. Trans. Amer. Fish. Soc. 98(3):478-486.

Gallaway, B. J. and K. Strawn. 1974. Seasonal abundance and distribution of marine fishes at a hot-water discharge in Galveston Bay, Texas. Contr. Mar. Sci. 18:71-137.

Gallaway, B. J. and K. Strawn. 1975. Seasonal and areal comparisons of fish diversity indices at a hot-water discharge in Galveston Bay, Texas. Contr. Mar. Sci. 19:80-89.

Grimes, C. B. 1971. Thermal addition studies of the Crystal River Steam Electric Station. Fla. Dept. Nat. Res. Mar. Res. Lab., Prof. Pap. Ser. 11:53 p.

Gunter, G. 1938. Seasonal variations in abundance of certain estuarine and marine fishes in Louisiana, with particular reference to life histories. Ecol. Monographs. 8(3): 314-346.

Gunter, G. 1945. Studies on marine fishes of Texas. Publ. Inst. Mar. Sci. 1(1):1-190.

Haedrich, R. L. and S. O. Haedrich. 1974. A seasonal survey of fishes in the Mystic River, a polluted estuary in downtown Boston, Massachusetts. Estuar. and Coast. Mar. Sci. 2:59-73.

Irwin, R. J. 1970. Geographical variation, systematics, and general biology of shore fishes of the genus Menticirrhus, family Sciaenidae. Unpubl. Ph.D. dissertation, Tulane Univ. New Orleans, La. 335 p.

Katz, M. and A. R. Gaufin. 1953. The effects of sewage pollution on the fish population of a midwestern stream. Trans. Amer. Fish. Soc. 82:156-165.

Kilby, J. D. 1955. The fishes of two Gulf coastal marsh areas of Florida. Tulane Stud. Zool. 2(8):175-247.

Kjelson, M. A. 1977. Estimating the size of juvenile fish populations in southeastern coastal-plain estuaries. p. 71-89. In Proceedings of the Conference on Assessing the Effects of Power-Plant-Induced Mortality on Fish Populations. W. Van Winckle, ed. Gatlinburg, Tennessee, May 3-6. 361 p.

Lagler, K. F. 1956. Freshwater Fishery Biology, W. C. Brown Co., Dubuque, Ia. 421 p.

Livingston, R. J. 1975. Impact of kraft pulp-mill effluents on estuarine and coastal fishes in Apalachee Bay, Florida, U.S.A. Mar. Biol. 32:19-48.

Livingston, R. J. 1976. Diurnal and seasonal fluctuations of organisms in a north Florida estuary. Estuar. and Coast. Mar. Sci. 4:373-400.

Mahadevan, S. 1976. Benthic Studies. Chapter 6, p. 183-276. In Tampa Electric Company, Twenty-fifth quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-second quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 350 p.

Margalef, R. 1958. Information theory in ecology. Gen. Sys. 3:36-71.

Martin, F. D. 1972. Factors influencing local distribution of Cyprinodon variegatus (Pisces: Cyprinodontidae). Trans. Amer. Fish. Soc. 101(1):89-93.

McErlean, A.J., S.G. O'Connor, J.A. Mihursky, and C.I. Gibson. 1973. Abundance, diversity and seasonal patterns of estuarine fish populations. Estuar. and Coast. Mar. Sci. 1: 19-36.

Morisita, M. 1959. Measuring of interspecific association and similarity between communities. Mem Far. Sci. Kyushu Univ. Ser. E. (Biol.). 3 (1): 65-80.

Mountain, J.A. 1972. Further thermal addition studies at Crystal River, Florida with an annotated checklist of marine fishes collected 1969-1971. Fla. Dept. Nat. Res., Prof. Pap. Ser. 20: 103 p.

Oesterling, M.J. 1976. Reproduction, growth, and migration of blue crabs along Florida's Gulf coast. University of Fla. SUSF-SG-76-003 19 p.

Phillips, T.D. 1976a. Ichthyoplankton. Chapter 5, pp. 260-317. In Tampa Electric Company, Twenty-sixth Quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-third quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 440 p.

Phillips, T.D. 1976b. Ichthyoplankton. Chapter 5, pp. 183-238. In Tampa Electric Company, Twenty-seventh Quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-fourth quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 440 p.

Phillips, T.D. 1977. Ichthyoplankton. Chapter 5, pp. 435-478. In Tampa Electric Company, Twenty-eighth Quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-fifth quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 651 p.

Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. J. Thor. Biol. 13: 131-144.

Reid, G.K. 1954. An ecological study of the Gulf of Mexico fishes in the vicinity of Cedar Key, Florida. Bull. Mar. Sci. Gulf and Caribbean. 4 (1): 1-94.

Renfro, W.C. 1961. Salinity relations of some fishes in the Aransas River, Texas. Tulane Stud. Zool. 8 (3): 83-91.

Roessler, M. 1965. An analysis of the variability of fish populations taken by otter trawl in Biscayne Bay, Florida. Trans. Amer. Fish. Soc. 94: 311-318.

Roessler, M.A. and D.C. Tabb. 1974. Studies of effects of thermal pollution in Biscayne Bay, Florida. Ecological Research Series. EPA-660/3-74-014. 145 p.

Shannon, C.E. and W. Weaver. 1963. The mathematical theory of communication. Univ. Ill. Press. Urbana. 117 p.

Simpson, D.G. and G. Gunter. 1956. Notes on habits, systematic characters and life histories of Texas salt water cyprinodonts. Tulane Stud. Zool. 4: 115-134.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical Methods. Iowa State University Press, Ames. 593 p.

Springer, V.G. and A.J. McErlean. 1962. Seasonality of fishes on a south Florida shore. Bull. Mar. Sci. Gulf and Caribbean. 12 (1) 39-60.

Springer, V.G. and K.D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay Area. Fla. Bd. Conserv. Mar. Lab., Prof. Pap. Ser. 1. 104 p.

Subrahmanyam, C.B. and S.H. Drake. 1975. Studies on the animal communities in two north Florida salt marshes. Part 1. Fish Communities. Bull. Mar. Sci. 25 (4): 445-465.

Tabb, D.C., and R.B. Manning. 1961. A checklist of the flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected during the period July 1, 1957 through September, 1960. Bull. Mar. Sci. Gulf and Caribbean. 11 (4): 552-649.

Tampa Electric Company. 1975. A summary and analysis of past ecological studies in the vicinity of the Big Bend steam electric station Tampa Bay, Florida. Submitted by: Conservation Consultants, Inc. R. Garrity, ed. 423 p.

Tampa Electric Company. 1977. Thirtieth Quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-seventh Quarterly report by Conservation Consultants, Inc. R. Garrity, ed. (In Press).

Tsai, Chu fa. 1968. Effects of chlorinated sewage effluents on fishes in Upper Patuxent River, Maryland. Chesapeake Sci. 9 (2): 83-93.

Turner, W.R. and G.N. Johnson. 1973. Distribution and relative abundance of fishes in Newport River, North Carolina. NOAA Tech. Report. NMFS SSRF-666: 23 p.

Whitehead, P.J.P. 1973. The clupeoid fishes of the Guianas. Bull. Br. Mus. Nat. Hist. (Zool.), suppl. 5.

Wickham, D.A. and F.C. Minkler, III. 1975. Laboratory observations on daily patterns of burrowing and locomotor activity of pink shrimp, *Penaeus duorarum*, brown shrimp, *Penaeus aztecus* and white shrimp, *Penaeus setiferus*. Contrib. Mar. Sci. 19: 21-35.

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CHAPTER NINE

A SUMMARY AND OVERVIEW OF THE '316 DEMONSTRATION' BIOLOGICAL STUDY AT BIG BEND, TAMPA BAY (FLORIDA).

BY

SELVAKUMARAN MAHADEVAN

AND

RICHARD D. GARRITY

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Copeland, B. J. and T. J. Bechtel. 1974. Some environmental limits of six Gulf Coast estuarine organisms. Contr. Mar. Sci. 18:169-204.

Dahlberg, M. D. 1972. An ecological study of Georgia coastal fishes. Fish. Bull. 70(2):323-353.

Dahlberg, M. D. and E. P. Odum. 1970. Annual cycles of species occurrence, abundance and diversity in Georgia estuarine populations. Amer. Midl. Nat. 83(2): 382-392.

Dragovich, A. and J. A. Kelly, Jr. 1964. Ecological observations of macroinvertebrates in Tampa Bay, Florida, 1961-1962. Bull. Mar. Sci. Gulf and Caribbean. 14(1): 74-102.

Finucane, J. H. 1969. Ecology of the pompano (*Trachinotus carolinus*) and the permit (*T. falcatus*) in Florida. Trans. Amer. Fish. Soc. 98(3):478-486.

Gallaway, B. J. and K. Strawn. 1974. Seasonal abundance and distribution of marine fishes at a hot-water discharge in Galveston Bay, Texas. Contr. Mar. Sci. 18:71-137.

Gallaway, B. J. and K. Strawn. 1975. Seasonal and areal comparisons of fish diversity indices at a hot-water discharge in Galveston Bay, Texas. Contr. Mar. Sci. 19:80-89.

Grimes, C. B. 1971. Thermal addition studies of the Crystal River Steam Electric Station. Fla. Dept. Nat. Res. Mar. Res. Lab., Prof. Pap. Ser. 11:53 p.

Gunter, G. 1938. Seasonal variations in abundance of certain estuarine and marine fishes in Louisiana, with particular reference to life histories. Ecol. Monographs. 8(3): 314-346.

Gunter, G. 1945. Studies on marine fishes of Texas. Publ. Inst. Mar. Sci. 1(1):1-190.

Haedrich, R. L. and S. O. Haedrich. 1974. A seasonal survey of fishes in the Mystic River, a polluted estuary in downtown Boston, Massachusetts. Estuar. and Coast. Mar. Sci. 2:59-73.

Irwin, R. J. 1970. Geographical variation, systematics, and general biology of shore fishes of the genus Menticirrhus, family Sciaenidae. Unpubl. Ph.D. dissertation, Tulane Univ. New Orleans, La. 335 p.

Katz, M. and A. R. Gaufin. 1953. The effects of sewage pollution on the fish population of a mid-western stream. Trans. Amer. Fish. Soc. 82:156-165.

Kilby, J. D. 1955. The fishes of two Gulf coastal marsh areas of Florida. Tulane Stud. Zool. 2(8):175-247.

Kjelson, M. A. 1977. Estimating the size of juvenile fish populations in southeastern coastal-plain estuaries. p. 71-89. In Proceedings of the Conference on Assessing the Effects of Power-Plant-Induced Mortality on Fish Populations. W. Van Winckle, ed. Gatlinburg, Tennessee, May 3-6. 361 p.

Lagler, K. F. 1956. Freshwater Fishery Biology, W. C. Brown Co., Dubuque, Ia. 421 p.

Livingston, R. J. 1975. Impact of kraft pulp-mill effluents on estuarine and coastal fishes in Apalachee Bay, Florida, U.S.A. Mar. Biol. 32:19-48.

Livingston, R. J. 1976. Diurnal and seasonal fluctuations of organisms in a north Florida estuary. Estuar. and Coast. Mar. Sci. 4:373-400.

Mahadevan, S. 1976. Benthic Studies. Chapter 6, p. 183-276. In Tampa Electric Company, Twenty-fifth quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-second quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 350 p.

Margalef, R. 1958. Information theory in ecology. Gen. Sys. 3:36-71.

Martin, F. D. 1972. Factors influencing local distribution of Cyprinodon variegatus (Pisces: Cyprinodontidae). Trans. Amer. Fish. Soc. 101(1):89-93.

McErlean, A.J., S.G. O'Connor, J.A. Mihursky, and C.I. Gibson. 1973. Abundance, diversity and seasonal patterns of estuarine fish populations. Estuar. and Coast. Mar. Sci. 1: 19-36.

Morisita, M. 1959. Measuring of interspecific association and similarity between communities. Mem Far. Sci. Kyushu Univ. Ser. E. (Biol.). 3 (1): 65-80.

Mountain, J.A. 1972. Further thermal addition studies at Crystal River, Florida with an annotated checklist of marine fishes collected 1969-1971. Fla. Dept. Nat. Res., Prof. Pap. Ser. 20: 103 p.

Oesterling, M.J. 1976. Reproduction, growth, and migration of blue crabs along Florida's Gulf coast. University of Fla. SUSF-SG-76-003 19 p.

Phillips, T.D. 1976a. Ichthyoplankton. Chapter 5, pp. 260-317. In Tampa Electric Company, Twenty-sixth Quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-third quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 440 p.

Phillips, T.D. 1976b. Ichthyoplankton. Chapter 5, pp. 183-238. In Tampa Electric Company, Twenty-seventh Quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-fourth quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 440 p.

Phillips, T.D. 1977. Ichthyoplankton. Chapter 5, pp. 435-478. In Tampa Electric Company, Twenty-eighth Quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-fifth quarterly report by Conservation Consultants, Inc. R. Garrity, ed. 651 p.

Pielou, E.C. 1966. The measurement of diversity in different types of biological collections. J. Thor. Biol. 13: 131-144.

Reid, G.K. 1954. An ecological study of the Gulf of Mexico fishes in the vicinity of Cedar Key, Florida. Bull. Mar. Sci. Gulf and Caribbean. 4 (1): 1-94.

Renfro, W.C. 1961. Salinity relations of some fishes in the Aransas River, Texas. Tulane Stud. Zool. 8 (3): 83-91.

Roessler, M. 1965. An analysis of the variability of fish populations taken by otter trawl in Biscayne Bay, Florida. Trans. Amer. Fish. Soc. 94: 311-318.

Roessler, M.A. and D.C. Tabb. 1974. Studies of effects of thermal pollution in Biscayne Bay, Florida. Ecological Research Series. EPA-660/3-74-014. 145 p.

Shannon, C.E. and W. Weaver. 1963. The mathematical theory of communication. Univ. Ill. Press. Urbana. 117 p.

Simpson, D.G. and G. Gunter. 1956. Notes on habits, systematic characters and life histories of Texas salt water cyprinodonts. Tulane Stud. Zool. 4: 115-134.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical Methods. Iowa State University Press, Ames. 593 p.

Springer, V.G. and A.J. McErlean. 1962. Seasonality of fishes on a south Florida shore. Bull. Mar. Sci. Gulf and Caribbean. 12 (1) 39-60.

Springer, V.G. and K.D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay Area. Fla. Bd. Conserv. Mar. Lab., Prof. Pap. Ser. 1. 104 p.

Subrahmanyam, C.B. and S.H. Drake. 1975. Studies on the animal communities in two north Florida salt marshes. Part 1. Fish Communities. Bull. Mar. Sci. 25 (4): 445-465.

Tabb, D.C., and R.B. Manning. 1961. A checklist of the flora and fauna of northern Florida Bay and adjacent brackish waters of the Florida mainland collected during the period July 1, 1957 through September, 1960. Bull. Mar. Sci. Gulf and Caribbean. 11 (4): 552-649.

Tampa Electric Company. 1975. A summary and analysis of past ecological studies in the vicinity of the Big Bend steam electric station Tampa Bay, Florida. Submitted by: Conservation Consultants, Inc. R. Garrity,ed. 423 p.

Tampa Electric Company. 1977. Thirtieth Quarterly report on the Big Bend thermal and ecological surveys. Contains Twenty-seventh Quarterly report by Conservation Consultants, Inc. R. Garrity, ed. (In Press).

Tsai, Chu fa. 1968. Effects of chlorinated sewage effluents on fishes in Upper Patuxent River, Maryland. Chesapeake Sci. 9 (2): 83-93.

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INTRODUCTION

The 316 Demonstration presented in the preceding six chapters (Chapters 3 to 8) encompasses four major biological components of the Big Bend ecosystem, namely,

Phytoplankton

Meroplankton (Invertebrate larvae and fish eggs and larvae)

Benthos

Nekton (Adult fishes and macroinvertebrates)

Water quality aspects (temperature, salinity, DO, pH and turbidity) of the study area were also intensively studied (Chapter 2). The study produced a voluminous amount of data which was presented in five quarterly reports. Data analysis was intensive and each of the preceding seven chapters provides information on the methods of collection and processing of samples, data management and analysis aspects, results of the study and a discussion of the results. Significant and relevant findings have been summarized at the end of every chapter.

This concluding chapter presents an overview and a general narrative summary of the significant findings of each of the seven studies. Impact assessment conclusions (or statements) generated from the seven studies are also presented. An attempt is also made to provide the reader with a comparative analysis of the three major biological components at Big Bend (Phytoplankton, Meroplankton and Benthos).

GENERAL SUMMARY

1. Hydrography

A primarily surface thermal plume was described. The plume generally extended 1.5 miles into Hillsborough Bay, but was highly influenced by tide, wind and other weather factors. At ebbing tide, the plume extended further westward and south along Apollo Beach. Ranges of average monthly differences in temperature between selected stations are presented below.

Stations	Average Monthly ΔT Range
Intake/Discharge	5.5 - 7.5°C
Discharge/P.O.D.	2.5 - 5.0°C
Dilution Pump Intake/ Dilution Pump Discharge	3.0 - 3.5°C
Source Water/Receiving Water	Equal
North Embayment/South Embayment	0.5 - 3.5°C

The plume generally exhibited a 45 - 66% decay in temperature from the discharge flume to the point of discharge to Hillsborough Bay. This means that on the average, temperatures at I-3 (point of discharge to Hillsborough Bay) were 2.5 - 3.0°C above ambient. Heated water remained close to the surface and seldom exceeded 6 feet in depth (average Bay bottom is approximately 15 feet). The plume configuration appeared greatly influenced by tidal stage and wind condition, and was often difficult to distinguish from large areas warmed by solar heating (nearshore stations, transects Z and Y, the most northern sampling transects, and stations south of Interbay Peninsula).

The bottom thermal plume was generally restricted to the immediate area adjacent to the point of discharge to Hillsborough Bay. Higher than ambient temperatures ($\Delta T \geq 1^{\circ}C$) were seldom noticed in the offshore stations (beyond 1 mile from the shore).

The north Apollo Beach embayment appeared influenced by tidal influx of heated water and subsequent dispersion at low tide. However, the embayment did not return completely to ambient temperatures (such as those in the south embayment) at low tide. (Extent of temperature reduction was to a level of about $1^{\circ}C$ above ambient). Fingerfill canals did not appear affected.

Maximum temperatures were recorded during the summer of 1976 (July - September) and were considered as "worst case" conditions. The $1^{\circ}C$ plume during this time was detected up to $2\frac{1}{2}$ miles offshore.

Spatial variations in salinity were not apparent. Temporal changes in salinity subjectively correlated with meteorological conditions.

Temporal and spatial variations in dissolved oxygen content and pH could not be attributed to the thermal effluent. Turbidity was higher in the discharge canal than offshore stations.

2. Phytoplankton

Phytoplankton sampling revealed a total of 133 species (83 species of diatoms, 42 species of dinoflagellates, and

8 species from other taxa) or nearly more than twice as many as reported in previous surveys of other portions of Tampa Bay. The phytoplankton community was nearly always dominated by a single species in high concentrations (_Skeletonema costatum_ in fall and winter, and a variety of successive dinoflagellate blooms in the summer, e.g. _Ceratium hircus_, _Gonyaulax polygramma_, _G. ditalis_). _Oscillatoria_ sp., a blue green algae (and suggested to be a thermally tolerant species) was the second most abundant species collected at Big Bend. (_S. costatum_ was the most abundant species collected at Big Bend). _Oscillatoria_ sp. was present in large numbers from mid-summer through early fall of 1976, and its abundance levels were moderately correlated to temperature. Similarly abundant levels of this species were recorded during the previous summer (August, 1975) also (i.e. prior to the operation of Unit 3).

The oligomictic nature of the phytoplankton communities at Big Bend (ten species accounted for over 90% of all phytoplankton sampled) made bioindices difficult to interpret.

A significant reduction in total seston biomass was noted at the*POD (1-3) when compared with the plant intake (1-6). The number of replicates taken for chlorophyll 'a'/phaeopigment determination were sufficient to detect only gross changes. Such changes between thermal and control areas were not evident.

Spatial variations in phytoplankton abundance or in bioindices were not apparent (although the latter were difficult

*POD - Point of thermal discharge to Hillsborough Bay.

to interpret due to the oligomictic nature of the community). Little difference in abundance, community structure, or total seston biomass was noted between the intake and discharge. Abundance temporally varied greatly at both stations.

A physical alteration to filamentous species (e.g. Oscillatoria sp.) was noted as numbers increased from intake to discharge suggesting that the filaments may be broken up as they pass through the power plant.

Except in the immediate vicinity of the thermal discharge (discharge canal - up to the point of discharge to Hillsborough Bay), no deleterious thermal or entrainment effects on the phytoplankton communities were discernable at the study site.

3. Benthos

A total of 352 species were recorded from the Big Bend area. Oligomictic conditions were common but were slightly greater in the thermal transect when compared with the non-thermal transect. Based on community parameters and abundance of dominant species, three identifiable faunal zones were demarcated. Zone I (discharge canal and station I-2) consisted of a pioneer environment characterized by low faunal density, high species diversity (H'), low species richness and an abundance of pollution indicator species. Zone II (thermal transect) was characterized by moderate diversity (H'), high faunal density, moderate species richness and low numbers of pollution indicator species. Zone III (non-thermal transect) was characterized by high species diversity (H′) moderate faunal density, high species richness and negligible numbers of pollution indicator species.

Based on an assessment of information collected on the abundance of fifteen dominant species, the discharge canal stations and station I-2 were shown to be detrimentally affected, the thermal transect stations and E-6 'mildly' affected (alteration, but possibly no deleterious effect), and station I-17 of the north embayment possibly 'mildly' (adversely) affected.

Probable impact on biomass was evident at stations I-1, I-16, I-2, I-17 and SP-2. During August, biomass was severely reduced at stations I-1, I-2, and I-17. An evaluation of the impact on community structure at Big Bend in relation to the thermal effluent revealed that the discharge canal and station I-2 were adversely affected. The adverse effect at station I-2 probably resulted from extreme solar heating and the thermal effluent. Thermal transect stations exhibited "altered" faunal conditions (detrimental effects were not clearly evident).

A cumulative impact assessment indicated that mildly adverse conditions due to the thermal effluent were restricted to a one kilometer radius from the discharge flume. The most persistent adverse impact was limited to the discharge canal (approximately 0.04 square kilometers).

Although faunal changes have occurred at some Big Bend stations since the start-up of Unit 3, based on the extensive sample collection and analysis of benthic data reported in this study, (876 petite Ponar Grab samples analyzed; 400,700 organisms counted; 352 species identified), it is believed that no significant impact had occurred to jeopardize the "protection and propagation of a balanced indigenous" benthic community at the study site.

4. Ichthyoplankton

Although spawning occurred during all sampling months, peak densities of both eggs and larvae occurred during spring and summer months. Larvae of 41 species were collected; however, eggs and larvae of the bay anchovy (*Anchoa mitchilli*) were more abundant than any other species during spring and summer (engraulids accounted for 73.1% of all eggs and 87.4% of all larvae collected). Sciaenids, represented by seven species of larvae, were second in abundance making up 26.2% of all eggs and 3.9% of all larvae. Clupeids accounted for 0.5% of all larvae and 0.2% of all eggs collected.

It is estimated that 1.858×10^{11} eggs and 3.855×10^{10} larvae were entrained by the plant during 1976. Egg entrainment was observed during all months except January, 1976. Larvae were entrained during every month of the study. The greatest amount of egg entrainment occurred in April, 1976. April, 1976 also was the month of highest larval entrainment.

Total sciaenid entrainment (seven species) during 1976 was estimated to be 1.252×10^{11} and 1.269×10^{9} for eggs and larvae, respectively.

H. jaguana entrainment occurred during the months of April through July, 1976. The estimated number of entrained eggs was 7.446×10^8. Larval entrainment was estimated as 7.196×10^7 individuals. A comparison of the number of eggs produced in the open bay area to the number of eggs entrained revealed that an estimated 0.22% impact on the spawned eggs is induced by the power plant (generating units and the dilution pump).

Bay anchovy, *A. mitchilli*, were investigated in greater detail than other species because of their abundance and their importance as a forage species. Estimated numbers entrained during 1976 were 5.795×10^{10} eggs and 3.352×10^{10} larvae. Comparison between the number of eggs produced by spawning at open bay stations and the number of eggs lost through plant entrainment showed that the loss represented only a small percentage (2.16%) of the total eggs produced in the study area.

Based on the assessment of the significance of entrainment of eggs for two dominant species at Big Bend (*A. mitchilli* and *H. jaguana*), it appears that entrainment effects on the dominant ichthyoplankton populations in the area are minimal.

Rearing experiments in bay anchovies indicated an average of 42% cropping of hatchable eggs through entrainment. Lowest hatching rates occurred in the summer months when abundance was highest and ambient and effluent water temperatures were highest.

5. Meroplankton (Invertebrate larvae)

The decapod crustaceans of the Big Bend area showed major spawning peaks through the warmer months of the year. This pattern is similar to that found in other studies along the northwest coast of Florida. Some depression of breeding occurred during the hottest part of the summer.

Large numbers of larvae were entrained through the Big Bend steam electric station. Decapod larvae entrainment alone was estimated to be 3 to 4.5 hundred billion in 1976.

A total of 105 taxonomic groups were recorded in the 363 μ mesh net samples. These included 86 of decapod crustacea taxa and 19 miscellaneous forms of 7 phyla (including Arthropoda). Eleven species accounted for about 91% of the individuals collected during the course of the study. Four species were dominant, occurred more frequently and accounted for approximately 80% of the total individuals collected in the study. They were: *Pinnixa sayana* (Average density = 148.41/m^3; 34.70%), *Polyonyx gibbesi* (Average density = 120.95/m^3; 28.28%), *Upogebia affinis* (Average density = 46.05/m^3; 10.77%) and *Neopanope texana* (Average density = 18.94/m^3; 4.43%).

Most of the decapod larvae found in the study area were non-commercial species whose adults are also residents of the area. The commercially important stone crab, *Menippe mercenaria*, was frequently collected, and though a minor part of the larvae, 2 to 8 million zoea of this species were entrained in 1976. Only 24 specimens of larval pink shrimp (<u>Penaeus dourarum</u>) were collected throughout this study. The offshore spawning behavior of this commercially important species appears to be the reason for the low numbers collected in the present study.

Estimates of invertebrate larvae other than decapod larvae were not realistic as the mesh of the net used in this study allowed many of these larvae to escape.

Entrainment estimates for the four most abundant species in the area (during 1976) are:

<u>Pinnixa sayana</u>: 3.151×10^{11}

<u>Neopanope texana</u>: 5.000×10^{10}

<u>Polyonyx gibbesi</u>: 2.088×10^{11}

<u>Upogebia affinis</u>: 6.805×10^{10}

and for the commercially important species, the stone crab, <u>Menippe mecenaria</u> is 7.012×10^{9}. These estimates include the entrainment of all three generating units and the dilution pump.

Entrainment of the species were seasonal in nature and generally matched seasonal abundance patterns of species in the area.

It was not possible to quantify the impact of entrainment of the larvae of any species on the adult population in the area with the data available. Lack of published information on the life histories of the meroplankton species collected at Big Bend and the absence of studies of the mechanisms by which their populations are maintained (i.e. compensatory mechanisms of the species, reproductive potential and strategies, etc.) were the primary reasons for not being able to assess the significance of the entrainment estimates.

6. Impingement of Fishes and Macroinvertebrates

A total of 9,382 macroinvertebrates (27 species) and 9,946 fishes (60 species) were impinged on either Unit 1 or Unit 2 during 744 sampling hours. The average rate of impingement for one unit was 302.6 macroinvertebrates and 320.8 fishes per day. Highest rates of impingement for both fish and macroinvertebrates were during the summer and winter months. Rates of impingement appear to be dependent on seasonal variations in abundance.

Pink shrimp (*Penaeus duorarum*), blue crabs (*Callinectes sapidus*), horseshoe crabs (*Limulus polyphemus*) portunid crabs (*Portunus gibbesii*), brief squid (*Lolliguncula brevis*), and mantis shrimp (*Squilla empusa*) constituted 84.8% of the total number of invertebrates that were impinged. Pink shrimp (*P. duorarum*) alone constituted 35.6% of the total invertebrate impingement.

Bay anchovies (*Anchoa mitchilli*), silver perch (*Bairdiella chrysura*), pinfish (*Lagodon rhomboides*), sand seatrout,(*Cynoscion arenarius*), leopard searobin (*Prinotus scitilus*), and Atlantic bumper (*Chloroscombrus chrysurus*) constituted 85.6% of the total number of fishes that were impinged.

Impingement at Big Bend does not appear to be significantly depleting the commercial stock in this area. Based on the 1976 commercial catch for Hillsborough County (Marine Fisheries Service, pers. comm.) one unit may have impinged approximately 0.23% of the commercial pink shrimp catch and 0.7% of the commercial blue crab catch. Extrapolated impingement data for one year indicated that one unit has the potential of impinging approximately 5.1% of the commercial catch of brief squid (L. brevis). Since rates of impingement vary with the seasons, these estimates are probably exaggerated.

Based on the data that was collected during 744 sampling hours between January, 1976 and March, 1977, it does not appear that impingement at Big Bend is significantly depleting the commercial fish and macroinvertebrate populations in this area.

7. Fishes and Macroinvertebrates

Intensive sampling (by trawl and seine) of the fish and macroinvertebrate communities in the vicinity of the Big Bend steam electric station was conducted between January, 1976 to March, 1977.

Seining (180 hauls) accounted for a total of 61,272 fishes (56 species; 32 families) and 647 macroinvertebrates (21 species). Day trawls (56 tows) accounted for a total of 2,109 fishes (26 families; 34 species) and 383 macroinvertebrates (24 species). Night trawling in February, 1977 accounted for an additional 4,349 fishes and 247 macroinvertebrates in 14 tows.

Throughout the course of the study, Menidia beryllina (tidewater silverside) and Fundulus similis (longnose killifish) were two of the most dominant fish species at several seine stations. The bay anchovy (*Anchoa mitchilli*), striped mullet (*Mugil cephalus*), scaled sardine (*Harengula jaguana*), sheepshead minnow (*Cyprinodon variegatus*), spotfin mojarra (*Eucinostomus argenteus*), silver jenny (*E. gula*), pinfish (*Lagodon rhomboides*) and spot (*Leiostomus xanthurus*) were the other abundant fish species collected in the area. Macroinvertebrates were dominated by the crown conch, *Melongena corona*. A few individuals of the commercially important macroinvertebrate species *Penaeus* duorarum (pink shrimp) and *Callinectes sapidus* (blue crab) were also collected.

In seine hauls, station SB-10 (northern embayment) accounted for 37.5% of the fishes and 54.1% of the macroinvertebrates that were captured during the course of this study.

The northern embayment station (SB-10) and, to a lesser extent, some adjacent stations appear to be functioning as nursery areas for a variety of species. No detrimental effects, due to the thermal discharge, were apparent in this area.

There was little correlation between temperature, salinity and: a) the total number of animals captured at each station each month; b) the total number of species captured at each station each month; c) the total number of animals captured at the outside stations (SB-5; SB-12; SB-14); d) the total number of animals captured at the inside stations (SB-10, SB-11, SB-13); e) abundance of a commercially important species (*Mugil cephalus*);

and f) abundance of Menidia beryllina (average temperature and average salinity values were used for this calculation).

Changes in numerical dominance and distribution were attributed to natural seasonal variation rather than to a deteriorating environment.

No significant differences in relative abundance or faunal composition were found between the seine stations during the course of this study. More importantly, the fauna at each seine station exhibited seasonal variations which appeared normal for this region. Actually, the Hillsborough Bay seine stations appeared to be removed from the direct influence of the warm water discharge. The temperature of the effluent has cooled considerably by the time it is discharged into Hillsborough Bay.

Since the area that was most susceptible to the effects of the heated effluent is small (discharge canal), the mobility of fishes will enable them to avoid this area during periods of excessive heating. This avoidance can easily occur without the loss of an irreplaceable habitat. The habitat created by the discharge canal does not appear to be vital to the survival of any particular species. Similarly, fishes can easily utilize this warm area during the winter months when ambient bay temperatures decline.

Seine station SB-12 is located close to the point of discharge into Hillsborough Bay. No significant differences in abundance and/or distribution that can be directly attributed to the effluent were found.

It appears that, overall, the discharging of thermal effluent into Hillsborough Bay is eliciting a negligible effect on the indigenous and transient fishes and macroinvertebrates in the Big Bend area.

8. <u>An Endangered Species</u>

Sporadic sightings of the endangered Manatee, *Trichechus manatus* were reported to the National Fish and Wildlife Laboratory Service in Gainesville, Florida. Sightings of the manatee in a thermally affected area is of particular interest. Hartman (1974) indicated that manatees seek a habitat where temperature fluctuations are minimal and, thus, may be attracted to a thermal effluent when ambient temperatures drop. The manatee may be stressed by low temperatures and the resulting weakened condition invites disease (Hartman, 1971).

Three sightings in the discharge canal were reported in 1976. Only one sighting, involving two manatees, occurred during the cooler months, winter (November 25). The other two sightings were in July and August involving three and five manatees, respectively.

9. <u>Overview</u>

The value of each of the studies included here in assessing a "balanced indigenous population" has been variable. As stated in the introductory chapter, impact assessment on nekton and plankton communities is plagued by wide variations in seasonal abundance, normal spatial patchiness, and the qualitative nature of sampling. We feel that we have been able to identify general trends and/or shifts in these populations and such conclusions as stated herein are perfectly valid. We have attempted to point out all the limitations of this study in the hope that no erroneous interpretations of our data would be made by us or construed by others.

Data on numbers of meroplanktonic organisms entrained by the power plant should be considered as estimates which are tempered by the "state of art" scientific limitations (e.g. sampling problems, patchiness, avoidance, etc.). Benthic studies, as predicted, have yielded the most complete array of quantitative data on community structure, and consequently the most complete impact assessment.

Generally, a lack of impact was noted for the benthos and for fish and macroinvertebrates in Hillsborough Bay. Adverse impact was found for benthos in the discharge canal. A light to moderate impact was found for phytoplankton only in the immediate vicinity (discharge canal) of the plant. Impingement rates appeared low and were insignificant for commercially important species when compared to commercial catches. Ichthyo-plankton and meroplankton (decapod larvae) were both entrained in extremely large numbers. An evaluation of the significance of the entrainment estimates on a species by species basis was not feasible due to lack of published life history studies on many of the species collected at Big Bend. However, an estimation of the entrainment impact on the eggs of two dominant ichthyoplankton species (Anchoa mitchilli and Harengula jaguana) showed minimal levels of cropping by the power plant (including the dilution pump).

An area of particular concern, the north embayment was seen to be inundated at least partially by thermal effluent (at high tide) and also to be greatly affected by solar radiation. Even so, this area contained the greatest number of fish and macroinvertebrates of any other area sampled and appeared to serve as a nursery area.

IMPACT ASSESSMENT CONCLUSIONS

Hydrography

Intensity of the spatial extent of the temperature increase due to the thermal discharge was limited to the surface water layers, to the discharge canal and to the nearshore areas in the vicinity of the power plant (less than 0.8 km from the point of discharge to Hillsborough Bay). The 1°C thermal plume was generally detected (surface only) up to a distance of approximately 2.3 km from the point of discharge to the bay and to a maximum of about 3.8 km in the summer. Spatial variations in other hydrographic parameters (salinity, DO, pH and turbidity) in the open bay appear unrelated to the thermal discharge.

Phytoplankton

Except in the immediate vicinity of the thermal discharge (discharge canal), no deleterious thermal or entrainment effects on the phytoplankton communities were discernable at the study site (subject to scientific limitations of the study).

Benthos

A cumulative impact assessment indicated that the mildly adverse conditions due to the thermal effluent were restricted to a one kilometer radius from the discharge flume. The most persistent adverse impact was limited to the discharge canal (approximately 0.04 square kilometers).

Although faunal changes have occurred at some Big Bend stations since the start-up of Unit 3, based on the extensive sample collection and analysis of benthic data reported in this study, it is believed that no significant impact had occurred to jeopordize the "protection and propagation of a balanced indigenous" benthic community at the study site.

Ichthyoplankton

Based on the assessment of the significance of entrainment of eggs of two dominant species at Big Bend, it appears that entrainment effects on the dominant ichthyoplankton populations in the area are minimal. Although large numbers of eggs and larvae were entrained by the power plant, the significance of the entrainment could not be evaluated due to a lack of published life history studies on the various species collected at Big Bend. However, in general, entrainment rates functioned as a variable dependent on seasonal abundance of various species in the open bay stations, and therefore, were higher only when populations were denser in the study area.

Meroplankton (Invertebrate larvae)

Large numbers of decapod larvae (3-4.5 hundred billion/year) were entrained by the power plant in 1976 (calculated using actual unit days for 1976). Approximately 7.012×10^5 zoea of the commercially important stone crab (*Menippe mercenaria*) were entrained in 1976. Not enough information is presently available on the life history of the decapod species collected in the area to assess the significance of the above entrainment.

Impingement

Impingement does not appear to be significantly depleting the commercial fish or invertebrate stock in the Big Bend area.

Fish and Macroinvertebrates

No immediate, significant, deleterious effects (except for possible seasonal effects in the discharge canal) on the fish and macroinvertebrate populations in the Big Bend area have been found, using methods as described in this study.

General

Results from the impact assessment studies described in this report appear to indicate that the operation of Unit 3 at Big Bend does not significantly alter the indigenous fish and shellfish populations of the receiving body of water (Hillsborough Bay). Also, entrainment effects of phytoplankton, and dominant ichthyoplankton and impingement effects appear to be minimal.

A COMPARATIVE ANALYSIS OF BENTHIC, PHYTOPLANKTON AND MEROPLANKTON COMMUNITIES AT BIG BEND

This analysis is presented to provide the reader an overview of the density, biomass and diversity (species richness) of three dominant components of the ecosystem at Big Bend, viz., Benthos, Phytoplankton and Meroplankton. Density is estimated as number of organisms/m^2 for the benthic fauna and as number of organisms/m^3 for the phytoplankton and meroplankton. (Meroplankton includes both fish and invertebrate larvae). Biomass is estimated as grams ash free dry weight/m^2 for the benthos and as milligrams ashfree dry weight/liter for the phytoplankton. Species diversity (species richness) is estimated as the number of species/station for all three groups. Only open bay subtidal stations have been utilized in this analysis. Station values were averaged for each sampling period (temporal point).

The results of this analysis should be viewed with caution because of the following reasons:

1) sampling intensity, both spatial and temporal, for the three components varies widely;

2) sampling methods and replication for the three components are different;

3) spatial variation for the three components were generally extensive (thus making the temporal points deviate widely);

4) factors governing the abundance and distribution of the three groups are different;

5) average life spans for the three groups are not uniform

6) power plant impact processes are essentially different for the three components.

The analysis is aimed at only providing estimates of the temporal patterns in the standing crop and species richness of the three essentially different trophic levels.

Faunal Density

Temporal trends in density were essentially similar between thermal and control open bay areas for all three components. Therefore, only average trends for the Big Bend area are presented in Figure 9.1. (Density values were log transformed). Temporal variation was far more extensive in the planktonic components than in the benthos. Decreases in benthos density generally followed decreases in the density of meroplankton (apparent correlation between secondary and tertiary trophic levels). Higher levels of abundance of phytoplankton generally appeared to deplete meroplankton abundance (This would be expected, since phytoplankton blooms tend to access the available water column, thereby pre-empting the meroplankton). The month of October was unusual in that both planktonic components were abundant. Meroplankton exhibited spring-early summer and late fall peaks in abundance, while phytoplankton exhibited a series of abundance peaks throughout the year. Benthos exhibited a

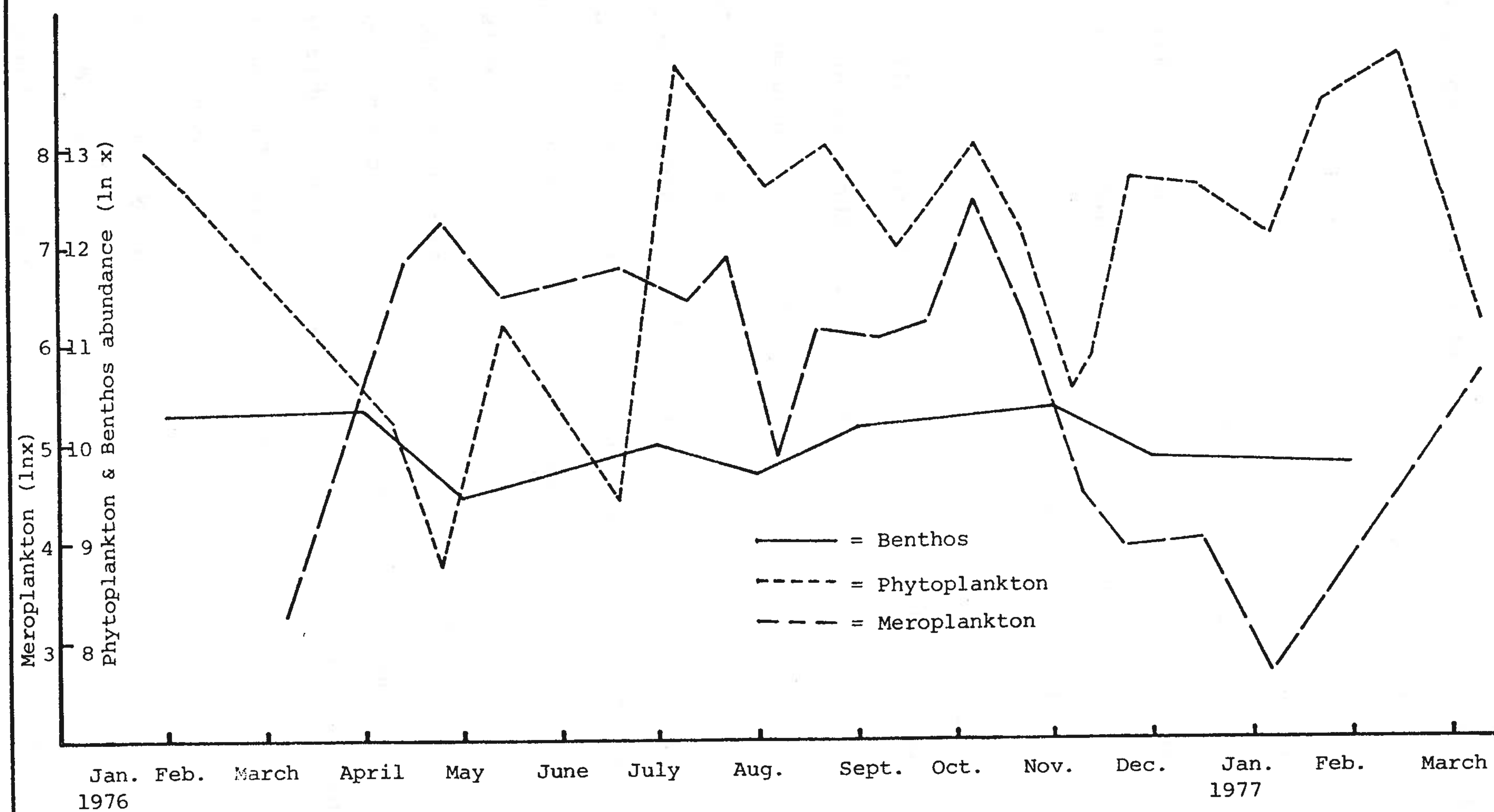

Figure 9.1. Comparison of faunal density between benthos, phytoplankton and meroplankton.

greater abundance in the fall and spring months.

Abundance of benthos and phytoplankton were relatively high when compared to the meroplankton.

Biomass

Biomass was estimated only for the benthos and phytoplankton (total seston). A comparative graph is presented in Figure 9.2. Both thermal and non-thermal areas are compared for the two components. Peaks in the biomass of the phytoplankton are matched with similar peaks for the benthos. An apparent lag appears to occur for the benthos suggesting a belated increase in biomass of benthos after the increase in the phytoplankton. Generally, no differences in biomass existed between the thermal and non-thermal areas for both components.

Species Richness

A comparative analysis of species richness for the three components is shown in Figure 9.3 (for thermal areas) and Figure 9.4 (for non-thermal areas). The benthic component was far more diverse than the planktonic components. While species richness was similar in both thermal and non-thermal areas for the planktonic components, the thermal areas exhibited a slight depression in species richness for the benthos.

Higher species richness was encountered for all three components during the fall months. Phytoplankton and benthos exhibited a higher species richness in the winter also. Mero-

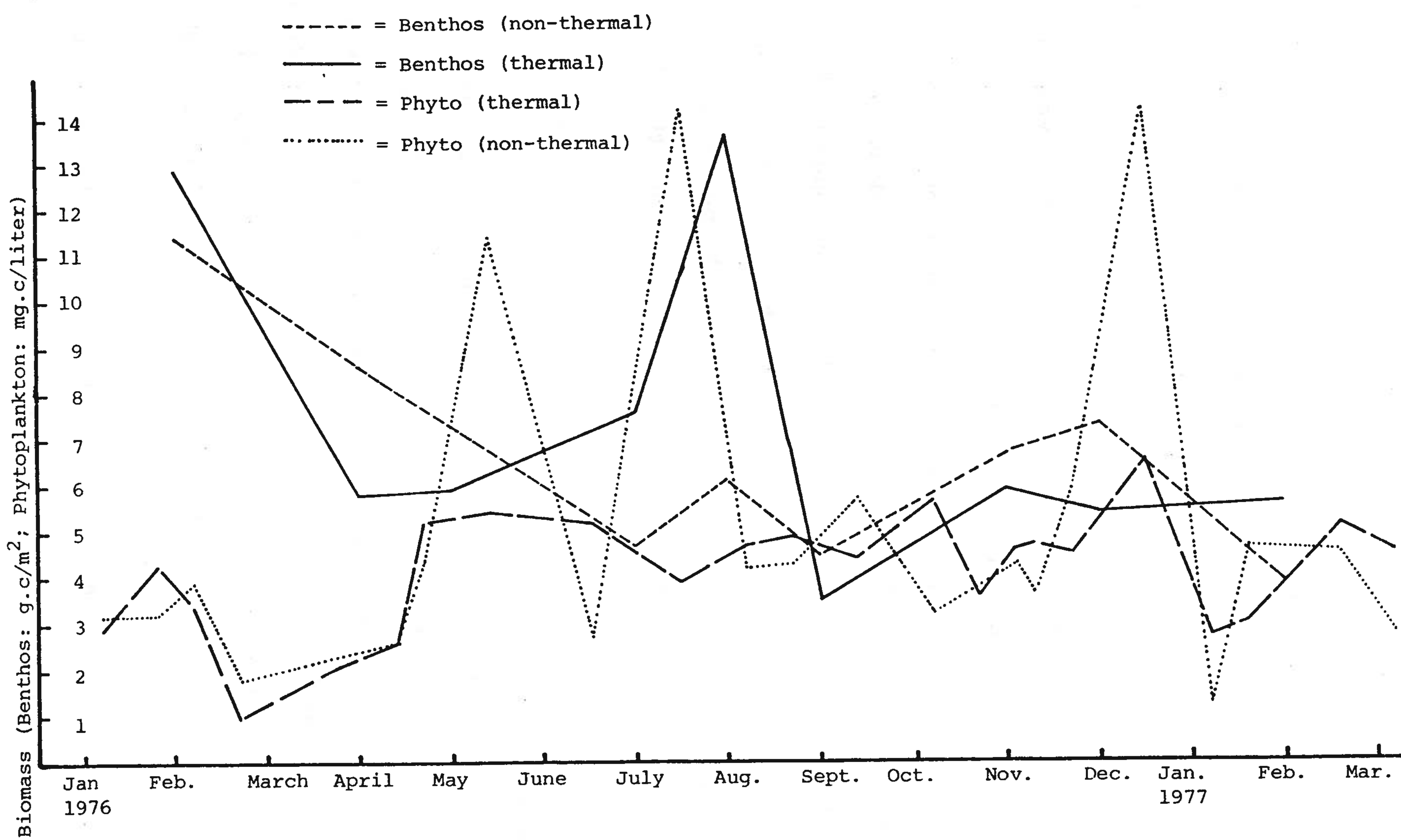

Figure 9.2. A comparison of biomass between the benthic and phytoplankton components.

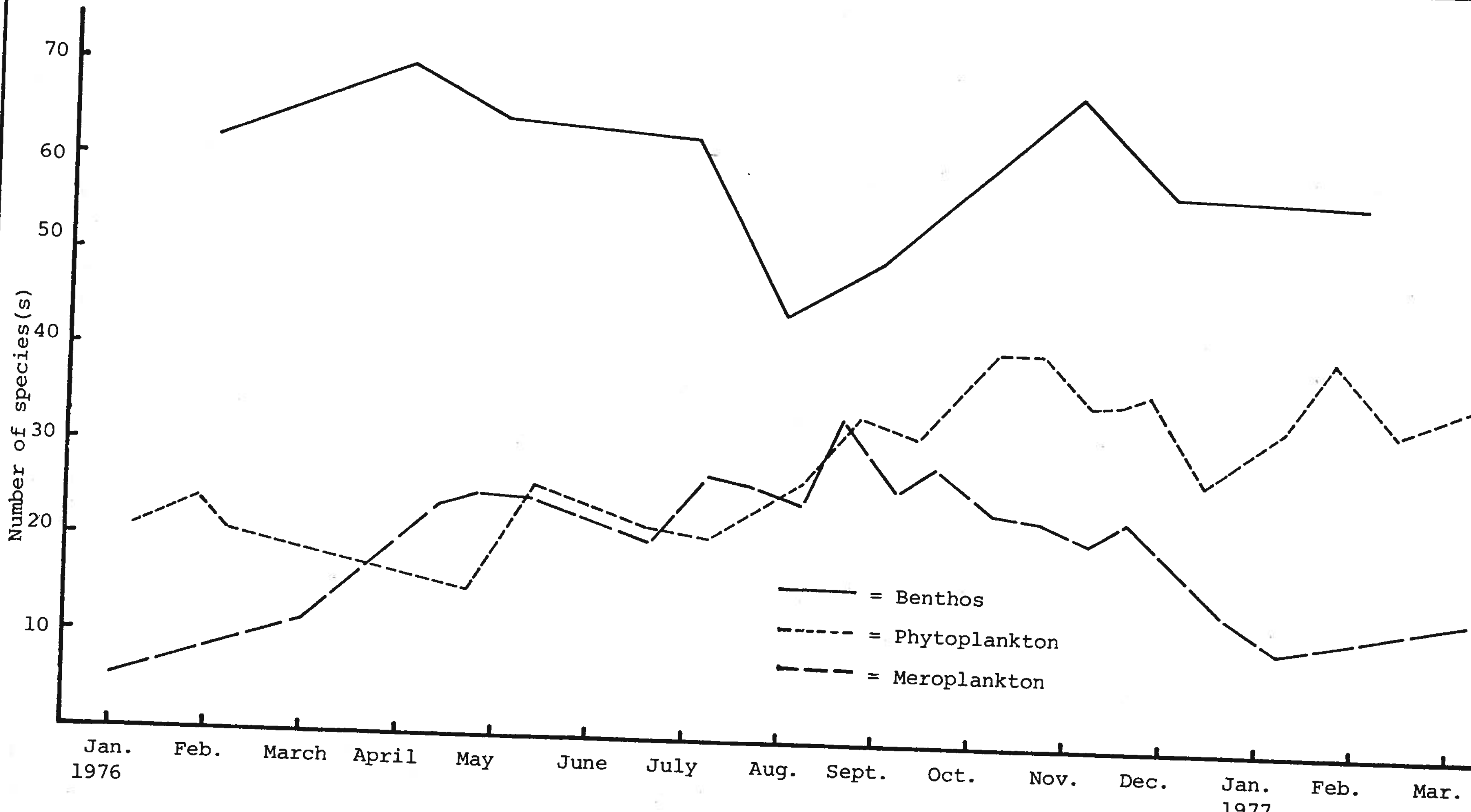

Figure 9.3. Species richness of benthic, phytoplankton and meroplankton components in thermal areas of Big Bend.

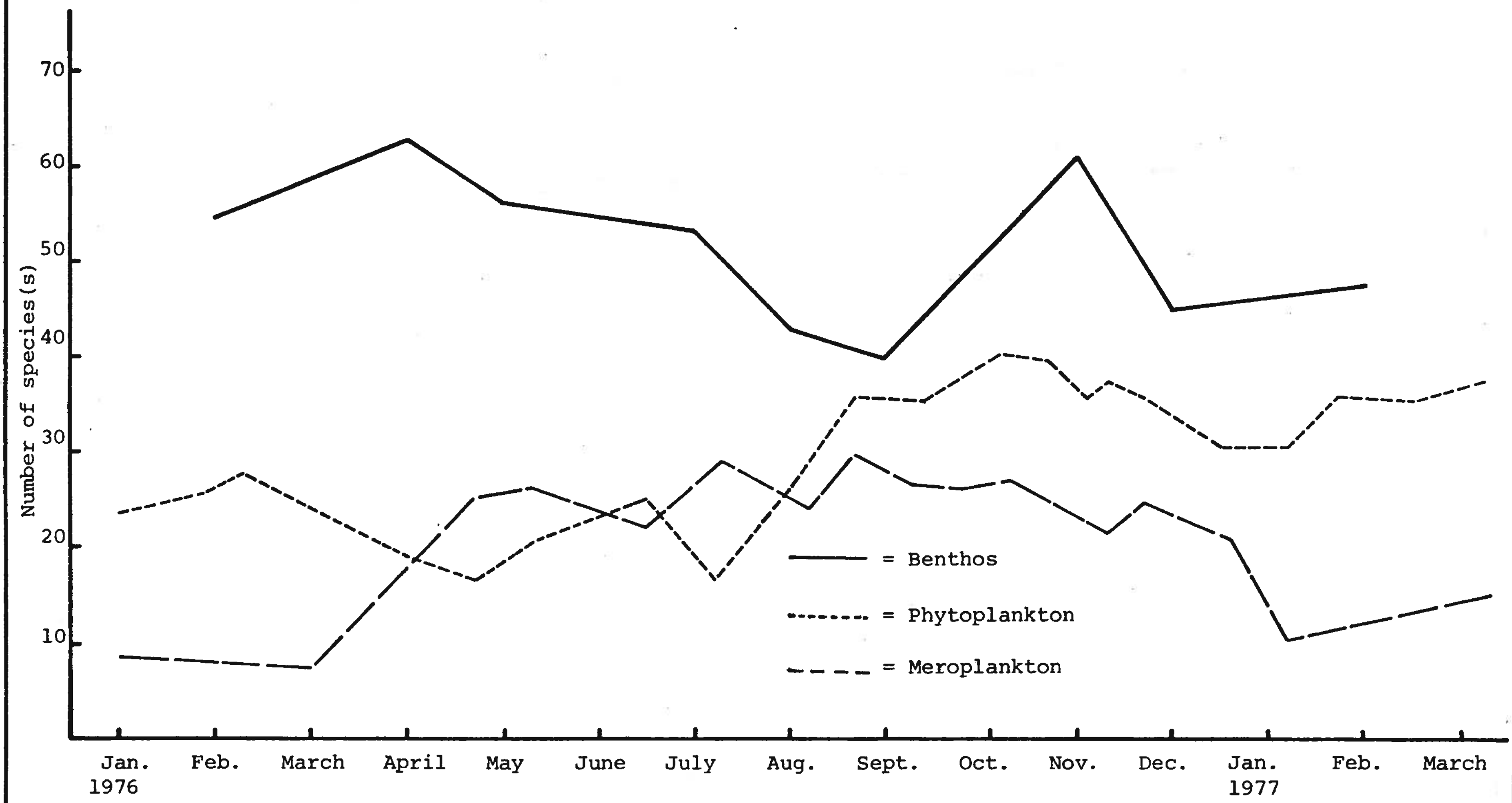

Figure 9.4. Species richness of benthic, phytoplankton and meroplankton components in non-thermal areas of Big Bend.

plankton contained a greater number of species during spring and summer months. Seasonal fluctuations in species numbers were more pronounced in the planktonic components.

General Considerations

In general, the planktonic components showed more extensive seasonal variations in density, biomass and diversity than the benthic component. This would be expected because of the short life spans (phytoplankton) or residing time (meroplankton) of the planktonic components. Overall, the Big Bend area appears to contain a diverse and dense benthic faunal assemblage but an oligomictic and physically controlled (controlled by hydrographic variations in the water column) planktonic community. This characterization would typically fit an estuarine system where benthic stability (and the abundance of niches) and water column fluctuations dominate (or control).

LITERATURE CITED

Hartman, D. 1971. Behavior and ecology of the Florida manatee, *Trichechus manatus latirostris* (Harlan) at Crystal River, Citrus County. Ph.D. Dissertation, Cornell University, Ithaca, New York, 285 pp.

Hartman, D. 1974. Distribution, status, and conservation of the manatee in the United States. Unpublished Manuscript, 247 pp.